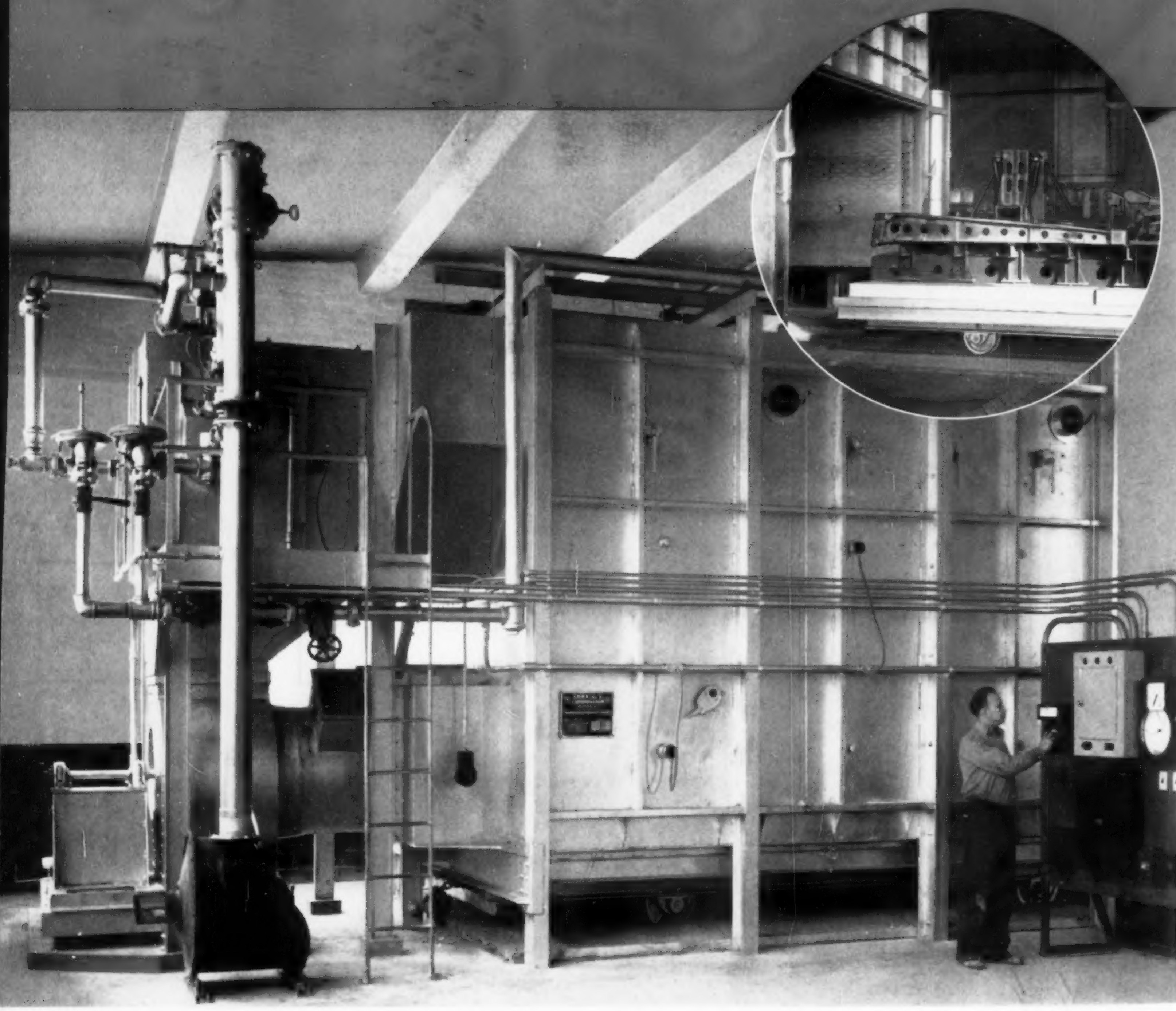
AMERICAN SOCIETY FOR METALS

METAL PROGRESS

APRIL
1939

A NEW TYPE SC CAR BOTTOM FURNACE



● In keeping with the decided trend toward heating by means of recirculated air (convection heating) Surface Combustion developed and recently installed several car bottom furnaces, for stress relieving and annealing, employing this principle of heating. Heat is supplied by one or more external gas fired air heaters located on top of the furnace. The hot products of combustion are distributed by means of a hot fan and ducts to the inside of the furnace. Here they are forced through the work sweeping all surfaces of the parts being heated.

After the hot gases have given up a portion of their heat, they are picked up by a recirculating fan and brought back to the air heater. Here they are mixed with fresh hot products of combustion and again delivered to the furnace.

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METAL PROGRESS

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The Cover photograph was taken by John P. Mudd for The Midvale Co.

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NOTES OF AN A.S.M. SPEAKER ON POWDER METALLURGY

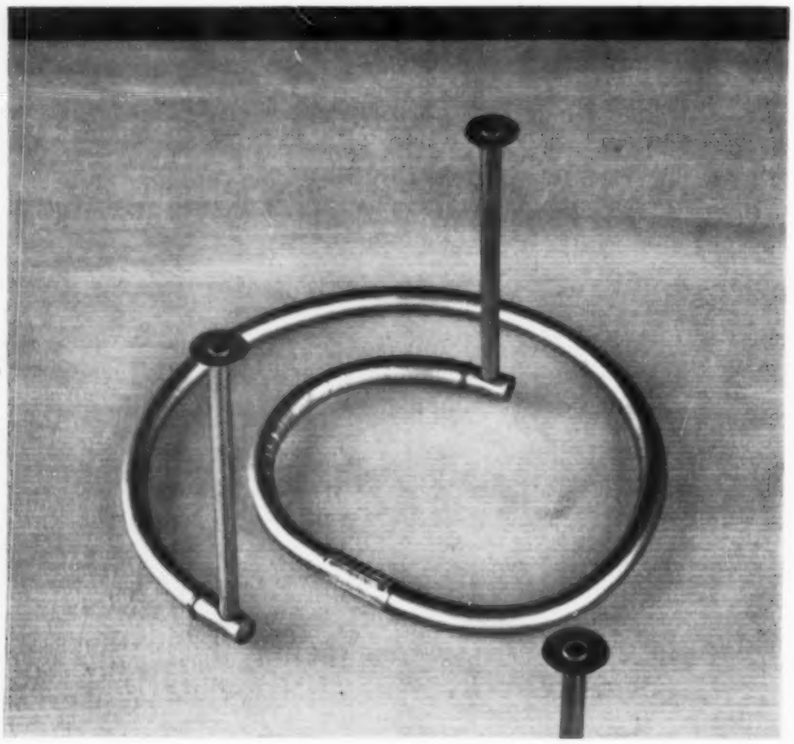
By Gregory J. Comstock
Manager
Metal Powder Products Division
Handy & Harman, Bridgeport, Conn.

IT IS curious what a miscellany of odd information is accumulated during the formative period of one's youth. It is never entirely forgotten nor absolutely discarded.

I personally acquired a notable addition to this sort of mental rag-bag in Washington when I was about 12 years old. Theodore Roosevelt was then President and the object of my very great admiration and hero worship. Much the President said that winter that was reduced to print eventually came under my eye. At a meeting of the Smithsonian Institute, Mr. Roosevelt, apparently being in a scientific turn of mind — doubtless induced by the company in which he found himself — called attention to the fact that the developing human embryo takes on a succession of forms which are historically suggestive of those required for the evolution of man in his development through the ages from a simple living cell to the present more-or-less finished product. As a striking example of these representative stages, he pointed out that at one period, presumably corresponding to man's derivative during a marine era, the foetus possesses gills. Continuing this thought, Mr. Roosevelt said that it was his personal opinion that one normal human life after birth would be found, in a similar manner, to be a pattern for the history of the entire human race, which, like it, passes from the irresponsible savagery of infancy through the strength and achievement of the prime of life and may in the future pass on to the doddering senility of old age and final extinction.

Following President Roosevelt's simile, powder metallurgy may be said now to have advanced to a stage where it has gills. It certainly has not yet developed sufficiently to enable us to delineate accurately its ultimate form. In other words, I am personally inclined to the belief that the art and science of powder metallurgy is as yet unborn.

Early Development — Historically speaking, the fabrication of metal powders began about a century and a quarter ago when the desire to melt platinum without contamination presented an exceedingly knotty problem. The metallurgist of that day found himself in difficulties when he worked with a metal which melted at a very high temperature (later found to be 3225° F.), absorbed carbonaceous gases with avidity and became unworkable when it did so. Any of us today, similarly confronted with obstinate nuggets of impure but valuable platinum and suddenly bereft of our improved refractories, controlled atmospheres and electric furnaces, would also be at a loss. Having a sooty coal fire, an inferior clay pot, a leaky pair of leather bellows and a strong right arm would not do much to help us out of our difficulties. One of our 18th century predecessors, however, used his head in this emergency in a very notable manner and in so doing became the true progenitor of powder metallurgy. Unfortunately his name has not been recorded with any degree of authenticity.



Tantalum Is Only One of the Refractory Metals That Have Been Commercialized Through the Technique of Powder Metallurgy. This is a steam coil for heating bromic acid. Photo from Clarence Balke of Fansteel Metallurgical Corp.

Platinum *powder* could be obtained at that time in a fairly pure state by chemical precipitation and reduction. This early metallurgist found that if he pressed this metallic powder into the form of small billets, and heated them to a temperature which was several hundred degrees below the true melting point of the metal, the mass consolidated or sintered to an extent that the hot slug could be forged. During the heat treatment of the pressed powder the individual particles apparently became fused or welded at their points of mutual contact. Repeated forging and heat treatment continued this bonding between particles and resulted in a dense, strong, and ductile metal from which articles could be fabricated by conventional operations such as those which were being currently applied to the common metals, such as copper. Casting, with its attendant difficulties and contamination, was rendered unnecessary. The process was also applied to the element iridium.

About 100 years later a similar but infinitely more difficult problem arising from the economic necessity for producing thin filaments of metallic tungsten for the incandescent lamp was found to respond to a modification of this same practice under the able manipulations of several of our most eminent elder contemporaries. Ductile forms of tantalum and molybdenum were also developed by similar powder technique. In fact, it became recognized that the extremely refractory metals *must* be fabricated from powders if they were to be economically produced in commercial quantities.

Influence of the Electrical Industry — These developments were confined to the electrical industry which had need for the refractory metals — indeed a fortunate circumstance, for it is extremely doubtful if the progress which has been made in this radical new departure from standard methods could have been achieved by any less versatile, progressive, and highly skilled engineering group. Time, money, and effort were intelligently applied without stint to the perfection of the processes for the production of refractory metals and the equipment and technique required for their manufacture from powder form. A visitor to any of the great incandescent lamp works is immediately impressed with the unusual equipment and the ingenious metallurgical operations which are being efficiently employed for the quantity production of the finest of filaments from the most refractory of the metals. When one considers the comparatively short time in years required for this development and its

Valves and Valve Seats of "Kennametal", Cemented Tungsten Carbide, for Use in Hydrogenation of Coal. Photo by courtesy of Philip McKenna

highly commercialized practical application, the true value of the accomplishment and the skill, industry and ingenuity of those responsible for it at once become apparent. Although it has been accomplished without fanfare in an almost surreptitious fashion, it is, I believe, an achievement which is almost without parallel in the whole history of applied metallurgy.

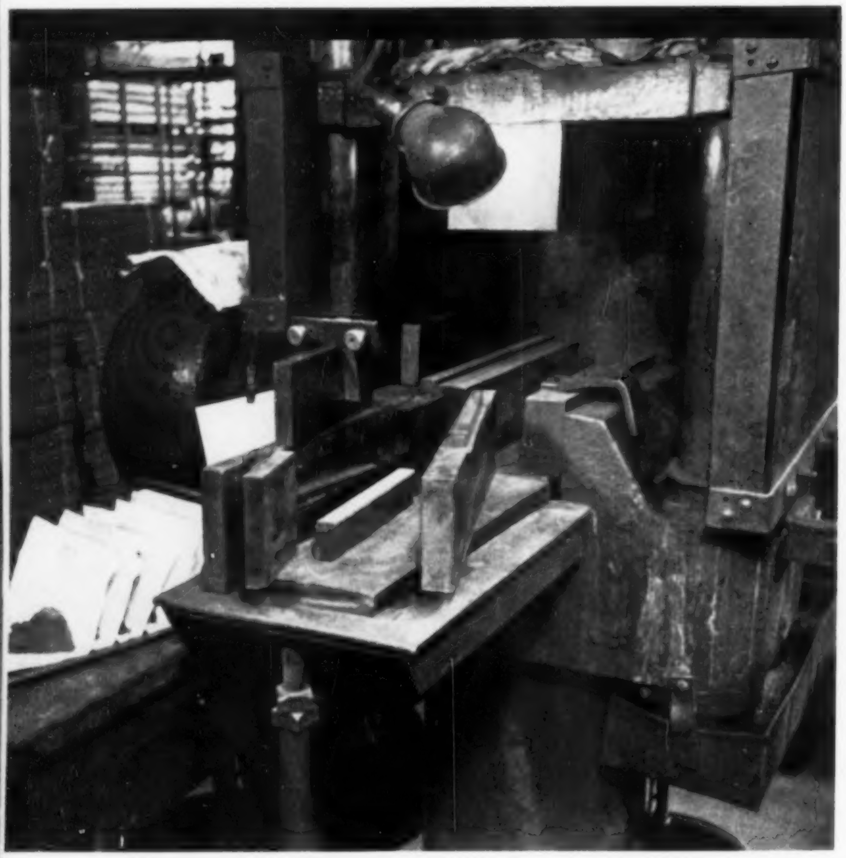
Hard Carbide Sinters Are Especially Useful as Tool Materials for Cutting Hard or Tough Materials That Ruin Toolsteels in Short Order. Note how tool made of titanium and tungsten carbides, "Cutanit", makes a roughing cut on a chilled cast iron roll. Photo courtesy of Paul Schwarzkopf of American Carbide Alloys Corp.

Further Developments — The familiarity with the possibilities of powder manipulation, the availability of the specialized equipment required for the fabrication of metallic powders, and the interest and impetus resulting from the successful development of ductile tungsten, resulted in the conception and development of three more major products of metal powder by the electrical industry. These are the porous metal bearing, the metal powder contact and electrode material, and the hard cemented carbide. As will be pointed out later, each of these has expanded far beyond the scope of the industry that mothered them.

Each of these new products has proved to be almost if not quite revolutionary in effect, and each has been responsible for an almost unprecedented progressive advance in the field of its particular application. Each was first received by industry with an amount of incredulity and reserve which very nearly amounted to suspicion, and which was most naturally engendered by their surprising performance and the novelty of the methods by which they were manufactured.

Metal powder bearings are now in wide general use and have been excellently developed by the automotive industry where they are in mass production. Metal powder contacts and electrode materials are standard products (of variable composition and form) which have greatly increased the effective production of the welding machine and the performance and safety of devices for interrupting currents. Hard cemented carbides have been responsible for the greatest upward revision of metal working and wire drawing practice that has ever been required for the development of a new tool material. These products with their predecessors (the ductile refractory metals, tungsten, molybdenum and tantalum) have, therefore, made a dominant place for themselves among our engineering materials.

It would be difficult if not altogether impossible to attempt any estimate of the technological progress for which these four established metal powder products are responsible, or even to summarize adequately their effect on the electrical and chemical industries or upon the fields of communication, welding, metal working and forming, machine construction and tool machine design. They have long since passed through their experimental development stages, are greatly in demand, and are all being made in permanent, well-established manufacturing plants which are periodically being expanded to permit greater production. To paraphrase Frank Palmer's recent excellent summary of the current improvements in toolsteels, these four established metal powder products are now being subjected to further improvements of their present generic forms



Elkonite Is a Material Much Used for Welding Electrodes and in Other Devices Where Good Conductivity and Stiffness Are Required. These properties are achieved by mixtures of copper and tungsten powders, pressed onto a copper bar as shown in demountable steel dies, or as separate slugs or shapes, and the compacts then heat treated and impregnated with copper or silver. Photo by courtesy of P. N. Cook of P. R. Mallory & Co.

and compositions by "small but significant developments which, taken together, are worth more than any single great discovery".

These four established types are made from powders of necessity. Either the character of their components or their structural forms are such that they cannot be made in any other manner. The processes of powder manipulation have, therefore, demonstrated their special aptitude for successfully overcoming difficulties insurmountable by other means. These special attributes of powder metallurgy must be considered as representing a technological improvement — a new tool — which was specifically forged to meet conditions where all other tools were useless. It would indeed be a strange and unprecedented reversal of history if this new tool would not be responsible for innovations and improvements when it is applied to the products of the former, less versatile practices.

The Present Situation — Powder metallurgy has now reached an interesting and important stage in its development. Conceived through necessity many years ago, it was intensively cultivated into specialized form by the electrical industry. Two of its first established products, however, have already carried the development into fields somewhat outside of the natural commercial territory of the electrical industry. The automotive industry and the manufacturers of tool materials are ably carrying on these developments in their respective fields. Those responsible for new developments in other industries are familiarizing themselves with the special attributes of powder metallurgy which might be applicable to their own products.

Many new applications of powder metallurgy have been considered; at least two have been developed to a point where production on a large scale is imminent. Several others are approaching this point. It appears quite likely that some of these newer metal powder products will occupy a field which has previously been regarded as the province of the normal melting and casting process. Certain factors are contributing to the invasion of this territory by powder methods; certain other factors have delayed or prevented such applications — chiefly functions of the process itself having to do with the special attributes and limitations of powder metallurgy in its present state of development.

Proprietary Rights — Powder metallurgy does not belong to any individual industry nor will its application ultimately be confined to any single manufacturing group. Its established products have unmistakably indicated that it may advantageously be applied to many diverse fields of industrial activity. In the future, however, as in the past, the first use of it and the profits which accrue from such initial applications will quite rightly belong to those who will have the foresight, initiative and industry to investigate and develop its application to their products.

There should be no fault to find with this on the part of others who have permitted the opportunities to pass them by. Ultimately the established processes of this or any other new development will be free for all to employ as they may see fit. The initial commercial advantages which resulted from the first expenditure of time, effort and money on the part of those

who have contributed to its development are little enough return for the services they have rendered.

To the Disturbed Conservative — Providence in Its wisdom has arranged the first developments of most forms of life to take place under conditions which assure protection at the sacrifice of visibility. We, therefore, do not see the child until it may withstand gentle handling. Nature has further protected newborn infants by generating a feeling of admiration for them in the hearts of their nearest relatives which is, perhaps, not altogether justified by their initial appearance and general characteristics. We are all of us upon occasion bored by the accounts of precocious children and yet this admiration serves its purpose as a further protective influence until the infant can take care of itself in the environment into which it has been so unceremoniously thrust. Households are disturbed and upset by the advent of a new arrival. Father finds his normal routine irreparably disjointed and his position in the household unmistakably on an altogether unfamiliar basis. Eventually the confusion subsides and the new life takes its place and proceeds upon its destiny as an integral part of the general scheme of things.

The ultimate arrival of powder metallurgy in a state of recognizable development will doubtless duplicate all of these conditions and carry out the analogy in considerable detail.

Father Hubbard, the glacier priest, recently described his last Arctic expedition and some of the queer birds he encountered. One of the most curious was the Alaskan variety of penguin called the "at-pat". The female of this species lays one egg every June. Providing its rather long incubation proceeds without mishap and the egg hatches, the at-pat lays no more eggs for that year. But if the egg is stolen (and at-pat eggs are an Eskimo delicacy), the female lays a second and if necessary a third and patiently incubates each one. Should the third egg also disappear or fail to hatch, however, she then takes desperate measures; believe it or not, she produces a *fourth* egg which hatches *immediately* with no incubation period whatever!

Like the first at-pat egg which did not hatch, the first product of powder metallurgy — refractory metal — did not emerge for general commercial application no matter how valuable it was to the electric lamp and its associated industries. The second — bearing, electrode and contact materials — was similar in this respect and may be said to have generated within the shell of a group of specialized industries or applications. The third egg — hard cemented carbides — has had a long, careful period of incubation; it has generated nicely but its own production processes have not been entirely representative of the greater possibilities of this new form of metallurgy.

Now comes the fourth and perhaps the critical egg which assures the life continuity of its maternal progenitor and requires little or no incubation period because of previous experience. Unless I am seriously mistaken, this product will be one which will be made from powders that are cheaply prepared from alloys — alloy powders, which will respond to the simpler forms of powder manipulation and which will find an immediate application in the largest field that has yet been affected by the processes of powder metallurgy.

"Oilite" Bearings and Bushings for Chrysler Automobiles Are Made in Its Moraine Products Division. Powder mixtures are first briquetted, heat treated and then sized in dies as accurate as a plug and ring gage. For production runs automatic dial feed is used on sizing presses such as the above (photographed in the Chrysler research department and used by courtesy of A. J. Langhammer)

Photo by Rittase at Alco Products

Fireworks in the Boiler Shop

A Welder is a Metallurgist and a Heat Treater, Even Unconsciously

WELDING OVERLAYS ON TURBINE BLADES TO PREVENT CAVITATION

By L. M. Davis
Hydraulic Test Engineer
Pennsylvania Water & Power Co.
and J. M. Mousson
Hydraulic Engineer
Safe Harbor Water Power Corp.
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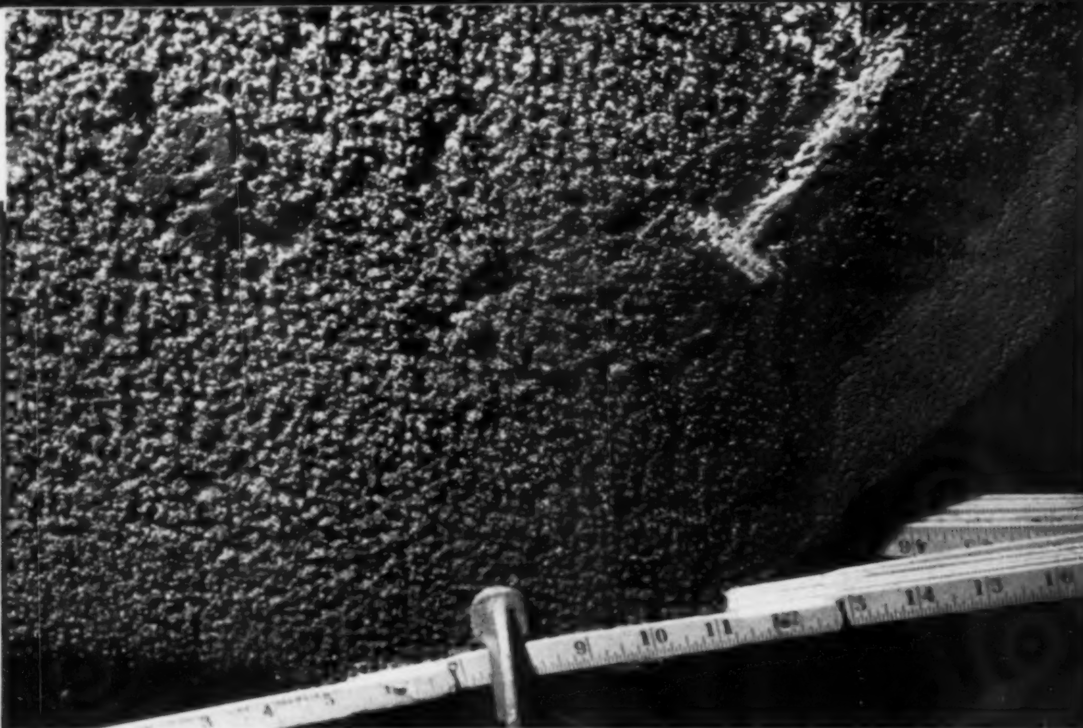
CAVITATION (the creation of a vacuum at the suction side of an impeller) and its destructive pitting action have seriously impeded the development of large hydraulic turbines, to say nothing of the damage to units already installed. Especially is this true of turbines of the Kaplan type, which work on the reverse of a ship's propulsion — namely, screw blades fixed to a vertical shaft are driven by the passing water. In Europe, where such turbines are more widely employed, it was soon found that cast carbon steel blades could not withstand the punishment. Believing that the pitting was in some way related to corrosion fatigue, blades of highly resistant 14% chromium steel (cast solid and heat treated) were substituted.

Although these blades were exceedingly expensive, their first cost was a small part of the entire generating unit, and it was believed that they would preserve their original performance characteristics, eliminate repairs with attendant shutdowns and loss of production, and postpone replacement indefinitely. For these reasons solid stainless steel blades have been widely adopted in Europe for turbines operating at heads of 30 ft. or more.

American engineers, lacking experience from such gradual developments, were not prepared to specify stainless steel blades on the first four large Kaplan turbines built in this country (Safe Harbor hydroelectric development on the Susquehanna River, 1931). Twenty blades were needed, each weighing about 12,000 lb. in finished condition. No foundry possessed the experience nor facilities to do the work, and none would assume the risk. Likewise the best analysis and heat treatment were unknown. Carbon steel blades were therefore ordered, realizing that pitting from cavitation would doubtless occur, but there would be ample opportunity for repair during the low-water months. Possibly a sufficient means for surface protection could meanwhile be found through experimentation.

Operating experience with these units showed that sizable areas on the suction side of the carbon steel blades were pitted after 18 months of service. Pitted areas were also noted on the peripheral surfaces where narrow clearances with the housings make repairs particularly difficult. Although pitting had by no means progressed to a point where the blades were seriously damaged, the affected areas were chipped to the solid parent metal, resurfaced with two coats of stainless 18-8 chromium-nickel steel electrodes and ground to a smooth finish. The particular material was chosen for

Paper Awarded Third Prize (Abridged), Functional Machinery Class, James F. Lincoln Arc Welding Competition



Pitted Area on a Cast Steel Blade of a Hydraulic Turbine After 18 Months Service, Caused by Cavitation (Development and Collapse of Vacuum) at Spots on the Suction Face

ating requirements had to be met. It was to be the first (and only one for some time) to generate 25-cycle, single-phase current for railroad motive power. Only infrequent and short shutdowns could be permitted, making it imperative that the punishment from cavitation should be ineffective or pitting at least reduced to a minimum. Since the carbon steel turbine blades had already been cast, it was felt that prewelding would likely be sufficient, provided the decision regarding the welding material could be made on a reliable basis.

units in place, because it was particularly suitable for this kind of welding which had to be done overhead. At the same time pioneering efforts on repairing cast iron Francis turbine runners at the nearby Holtwood plant of the Pennsylvania Water & Power Co. had shown the excellent resistance of 18-8 weld deposits. While the results obtained at Holtwood were satisfactory, it was thought that cavitation at Safe Harbor might be more severe and it was not at all certain that this material would prove adequate in that location.

Subsequent inspection showed that the repaired areas stood up satisfactorily. The smooth ground surface of the deposits revealed effects of cold working as though it was peened. The unevenness on the surface could hardly be felt by hand and was best discernible by lighting effects. However, marked pitting was again discovered on a wide band of parent metal immediately adjacent to the welded areas. In view of this, it could be surmised that periodic repairs would continue until the welded areas had reached the boundary zone of cavitation.

In 1933 an identical fifth unit was installed at Safe Harbor. The peripheral surfaces of the blades, difficult to weld in the field, were prewelded in the shop with 18-8 chromium-nickel electrodes.

In 1934 the installation of a new unit was contemplated, but for this turbine special oper-

In order to gain experience rapidly, an extensive research was initiated. A special apparatus was built providing accelerated testing conditions, so that a test run of only 16 hr. would correspond to several years' service at

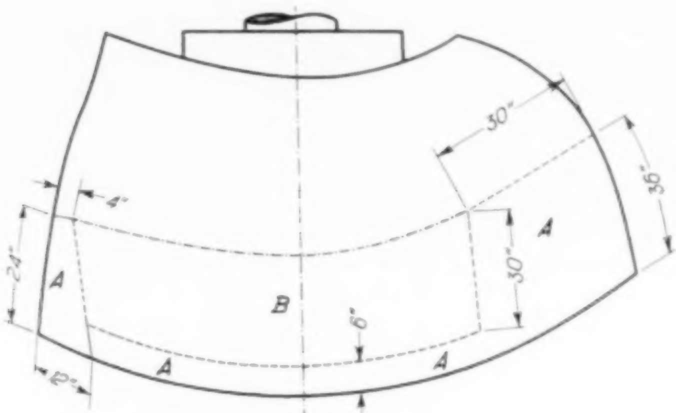
Specimens (¼x¼x4 In.), Machined and Ground, Were Subjected to Intensive Cavitation for 16 Hr.; Pitting Evaluated by Volume Lost in Cubic Millimeters (Weight Loss and Density Determined)

Safe Harbor. Although this research was later extended to include cast, rolled, forged, acetylene welded, and sprayed materials, it will suffice here to discuss the results obtained with electric arc welding deposits. Details of equipment and results may be consulted in two papers by the junior author, one in *Transactions* A.S.M.E., July 1937, and the other in *Bulletin* of Edison Electric Institute, Sept. and Oct. 1937.

It should be emphasized that pitting resistance by itself could not be used as the only criterion; manufacturing procedures had also

to be given careful consideration to arrive at the proper solution, which, while a compromise, could best satisfy all requirements.

In view of the problem to be met, most interest centered in the tests on samples of welded overlays. In general, these were made in two layers to protect the outer layer from contamination or dilution from the basis metal.



Regions A Were Surfaced With 18-8 Weldrod; Some Cavitation Later Developed in Region B

From welding practice in general, it is known that carbon may be picked up from the basis metal by the first layer. In the light of the metallographic analysis of many specimens, free carbon may substantially lower the pitting resistance because any impurities (and carbon in this case must be regarded as such) may serve as nuclei for fatigue cracks or may promote rapid progress of cracks toward their location. Two layers of welding materials were regarded as a minimum, since the carbon content of the new turbine blade castings was about 0.30 to 0.45%. At the same time the loss in chromium and other alloy constituents could be expected to be appreciably higher in the first layer than in the second.

Since the cavitation loss in the accelerated test (16 hr.) of the Safe Harbor turbine steel was found to be 62.4 cu.mm., it is interesting to find that low carbon and low alloy steels generally are in the same range. Tests show, for instance, that weld deposits of plain steels with carbon of 0.07 to 0.13% (analyses in all cases are of metal in the deposit) had cavitation losses of 67 to 76 cu.mm. Low alloy steels were no better: 0.50% Mo, 0.12% C steel lost 87 cu. mm.; 2.3% Ni, 0.30% Mo, 0.08% C steel lost 68 cu.mm. Higher alloy deposits showed marked improvement: 8.0% Mn, 0.10% C lost 39 cu.mm., and 5% Cr, 1.5% Mo, 1.25% C lost 18.6 cu.mm.

This last figure indicates a general trend, namely, that high chromium-iron alloys (hardenable stainless steels) showed the greatest resistance to cavitation, and the austenitic chromium-nickel steels somewhat less. Representative values are shown in the table.

It was also observed that the harder the deposit the smaller the loss. Some inconsistencies may readily be explained by susceptibility to increase in hardness during cold working. The Brinell hardness given was obtained on areas not subjected to cavitation; Rockwell tests in the pitted zones showed an increase in hardness which was more pronounced for the materials having better cold working characteristics, such as the austenitic 18-8 and 24-12 varieties of chromium-nickel steels. It may be surmised that if high original hardness could be combined with a high susceptibility to strain hard-

Cavitation Loss (Cu.Mm. in 16 Hr.) of Various Two-Layer Welded Deposits

Chromium Steels and Irons				
Type Analysis			Brinell Hardness	Cavitation Loss
Cr	C	Ni		
12.5	0.06	0.60	315	8.2
13.3	0.06	0.45	346	9.6
15.7	0.06	0.09	349	8.8
16.5	0.16	0.78	293	5.3
17.7	0.06	1.43	390	7.8
18.2	0.13	0.21	350	6.9
19.2	0.07	0.09	222	17.7
21.5	0.28	1.02 Cu	374	4.0
28.0	0.10	....	262	11.1
28.0	0.09	4.25*	256	3.5

*Plus 1.5% Mo

Austenitic Chromium-Nickel-Iron Alloys					
Type Analysis				Brinell Hardness	Cavitation Loss
Cr	Ni	C	Other		
17.4	7.5	0.11		373	1.3
17.8	8.9	0.12		206	23.4
17.7	10.6	0.06	2.4 Mo	215	25.4
17.2	11.3	0.05	0.9 Cb	233	13.7
18.2	8.8	0.07		230	8.2
18.5	9.0	0.07	3.0 Mo	227	16.8
18.4	25.3	0.05		162	24.6
19.2	8.6	0.05		222	8.5
19.9	9.8	0.04	0.25 Ti	198	14.3
20.7	7.7	0.06		192	31.9
20.5	9.7	0.05		192	9.8
20.5	9.7	0.05	1.5 Mn	191	25.8
20.4	9.4	0.07	0.65 Cb	193	16.2

ening or cold working, such a material would be exceedingly resistant to pitting. This is clearly shown by the specimen in the first line of the right-hand column (page 351). Here the chromium and nickel in the deposit approached the 17-7 ratio, and this alloy is somewhat unstable, showing martensite interspersed through the austenite matrix. This accounts for high original hardness, and at the same time a 17-7 or 16-6 chromium-nickel alloy is more susceptible to cold working than the 18-8 or 24-12 varieties.

Comparative Costs of Solid and Prewelded Turbine Blades

Type and Chemical Specification	220-In. Runner		100-In. Runner	
	Ground Only	Machined & Ground	Ground Only	Machined & Ground
Cast carbon steel 0.30 to 0.40 C, 0.60 to 0.80 Mn < 0.035 P or S	100 (Base)	146	100 (Base)	150
Same, prewelded with 18-8	136	193	140	195
Cast chromium steel 11.5 to 13.0 Cr, < 0.12 C, < 0.50 Mn < 0.035 P or S, < 0.50 Si; 1 to 2 Ni, 0.40 to 0.60 Mo, > 0.10 V	220	283	185	242
Cast chromium-nickel steel 16 to 17 Cr, 6 to 7 Ni, < 0.25 C < 0.50 Mn, < 0.035 P or S, < 0.50 Si	250	312	210	267
Same, but low carbon (< 0.07 C)	280	340	240	300

Although there was definitely a higher average resistance indicated by the straight chromium steels, it was not at all certain whether such would be desirable, since the hardness of the deposit might cause difficulty in machining and grinding. To arrive at a conclusion, special tests for machinability were, therefore, deemed essential.

In order to eliminate as many variables as possible, the tests for machinability were made on a spare cast steel turbine blade having the same composition as the Safe Harbor blades. Double layer deposits of seven of the most promising varieties of electrodes were made, each deposit covering an area about 6x4 in. Careful notes were kept as to the comparative ease of welding, the time required to weld, and the pounds of deposit per pound of welding rod. Each deposit was then machined on the same tools as later to be used for the Safe Harbor turbine blades. Maximum machining speed and power input were determined. Due to the curved surface of the blades, it was necessary to use a round point cutter, which left ridges between the cuts. After machining the test deposits, the ridges were ground off and the entire surface polished.

Visual inspection showed that six of the seven specimens resulted in a very good surface, the seventh being pock-marked with gas holes. Three of the six good specimens were machined with difficulty, due to non-uniform hardness. Another was exceedingly hard, so that considerable difficulty with cutters might be expected. Of the two specimens which passed the machinability test, one deposit was somewhat easier to apply than the other, resulting in the adoption of the 18-8 chromium-nickel welding electrode noted in the fifth line of the right column in the table.

Experience with the five units already operating at Safe Harbor made it possible to predict what portions of the blades should be prewelded. The blades were rough machined and then the areas to be welded (shown in the sketch, p. 351) machined $\frac{3}{16}$ in. below the finished blade surface. Ridges left by the tool were ground off, and any flaws chipped and repaired with mild steel weld rod.

To prevent warpage of the relatively thin blades, varying from 1 to $3\frac{1}{2}$ in. thick, they were placed in circulating water so that only the portion of the blade to be welded was dry. In order to weld the periphery, the blades were held vertically and rotated as the welding progressed so that the welding could be done in the horizontal. A double layer was deposited throughout. Approximately 1800 lb. of $\frac{5}{32}$-in. coated electrodes was required for the five blades.

After welding, the blades were checked for shape, and very little distortion had resulted; there was no difficulty in springing them back.

In finish machining it was found that the welded areas could be cut practically as fast as the parent metal. The quality of welding was excellent; there were only a few places where it was necessary to do any patch welding. The round-nose cutter left ridges which were ground off and then the surface was carefully polished. The finished blades assembled in the hub are shown opposite; the prewelded areas appear lighter than the parent metal.

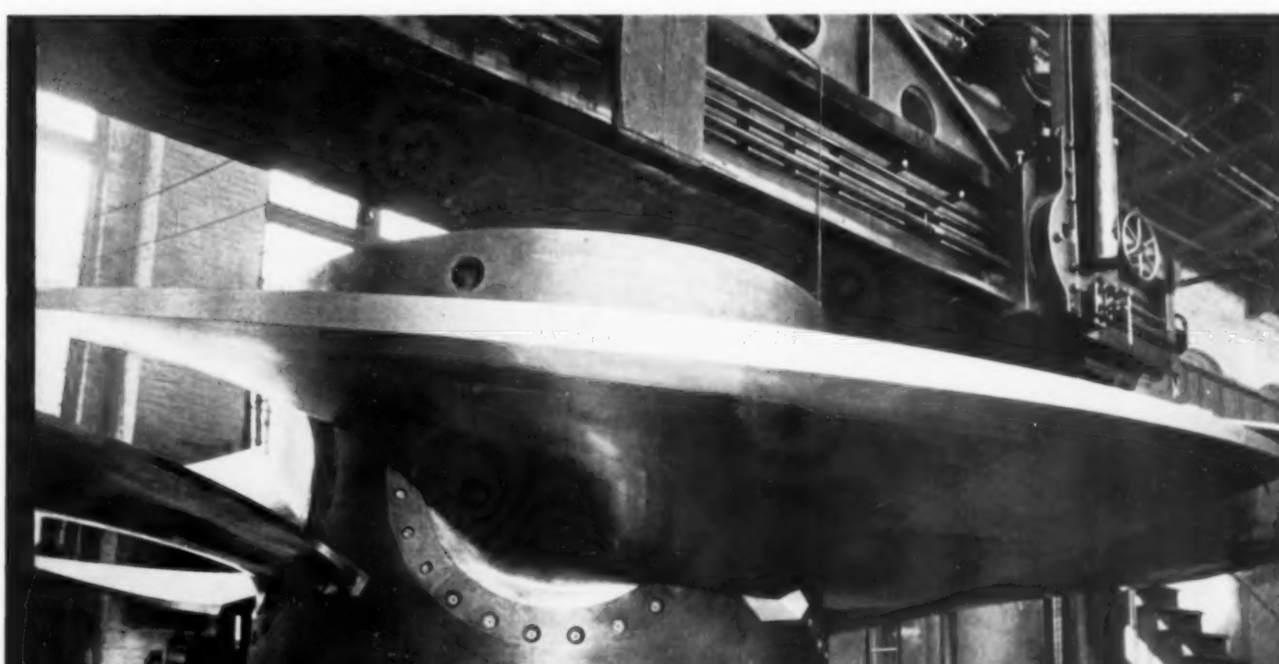
While prewelding with stainless 18-8 electrodes proved advantageous for the new Safe

Harbor unit, for other installations welding electrodes of a different type may be considered. For instance, where machining of the runner blades should also impose some limitations on hardness of the welding deposit and where cavitation by corrosive or salty water is expected to be severe, an austenitic 18-8 chromium-nickel steel alloyed with 3% molybdenum will result in a deposit of higher pitting resistance and may give adequate service. On the other hand, where easy machining is not required and therefore no limitations are set on the original hardness of the welded areas except with a view to grinding, and at the same time very severe cavitation conditions are expected, austenitic 17-7 or 16-6 chromium-nickel deposits, or one of the stainless chromium steels could be chosen with advantage.

With stainless chromium steel electrodes, containing 12 to 14% chromium (with or without small additions of nickel), some precautionary measures should be taken to prevent the formation of hair cracks or zone cracks. These cracks are due to the air hardening characteristics of this alloy. Based on field experience with areas so built up and in service over a period of years at Safe Harbor, it may be concluded that neither hair nor zone cracks are conducive to pitting. Certain objections may, however, be raised from a structural point of view, particularly with respect to the deeper zone cracks, and both types of defects are undesirable from a manufacturing standpoint. These imperfections can be prevented either by keeping the carbon content below 0.08%, or by depositing on the parent metal an insulating layer of 18-8. This layer not only prevents the infiltration of carbon but, due to its excellent ductility, it may stretch or contract along the two boundaries that are adjacent to the basis metal and the chromium steel top layer.

The economic considerations of prewelding are of fundamental importance. Taking advantage of recent progress in the casting of stainless steel in this country, quotations were obtained from several turbine manufacturers on solid cast stainless steel blades. These cost data in index form are presented on page 352. Relative values were chosen rather than absolute to preserve the usefulness of this table,

Completed Runner Blades in Plant of S. Morgan Smith Co. Prewelded portions on the under side and edge of near blade are clearly indicated by their different reflectivity



even if material and labor cost should vary.

Three types of stainless steel castings were selected on the results of an exhaustive laboratory research on the pitting resistance of cast stainless alloys. For the austenitic chromium-nickel steel castings, chromium and nickel were kept on the low side to obtain the most hardening by cold work. To improve the hardness of the stainless chromium steel, 1 to 2% of nickel was specified, while molybdenum and vanadium serve as essential grain refining agents. No differentiation was made as to the various electrodes used for the prewelded design because the price range is rather narrow. It was assumed further that somewhat more than 50% of the suction face of the propeller blades is to be prewelded, all of the peripheral blade surfaces, as well as the entire trailing edges as shown in the last sketch. It is evident that for a 220-in. diameter runner with today's index base (100 for five cast and finished ground blades at $21,000), the saving by means of prewelding amounts to $17,500 over cast stainless chromium steel blades, $24,000 over cast high carbon chromium-nickel steel and $30,000 over cast low carbon chromium-nickel steel. The corresponding savings for machined and ground blades for the same runner diameter are $19,000, $25,000 and $31,000, respectively.

From the trend of the index figures, it may be noted that the economic aspect varies with the size of the runner. A point may be approached for very small turbines where cast chromium blades may be as economical as prewelded runners, but the increasing advantage of prewelding is apparent for larger sized units than those mentioned in the table. For five blade runners of 260 to 280 in. diameter, for hydroelectric plants under construction in this country, the savings should be 40 to 50% above those determined for the 220-in. runner.

Prewelding as developed for this large capacity low head turbine of the propeller type has been found entirely feasible in manufacturing and satisfactory in service. A recent inspection, after three years of continuous service, showed that the prewelded areas were undamaged. The experimental installation for Safe Harbor has been so successful that prewelding of the turbine blades was specified for the large turbine runners manufactured during 1937 to be installed at the Bonneville project and the Pickwick Landing dam. Prewelding of blades is also being considered for the Chickamauga and Guntersville developments.

UTILITY OF AGE HARDENING

By Marie L. V. Gayler

Extracts from The Metallurgist, *Supplement to* The Engineer, *Dec. 30, 1938, p. 181*

ALTHOUGH DENTAL ALLOYS had long been made of compositions which responded to precipitation hardening and tempering, and Wilm discovered a hardenable alloy of aluminum (duralumin) in 1906, it was not until 1919 that Merica, Waltenberg and Scott advanced their theory of "dispersion hardening" to explain the phenomenon — since discovered to be a property of numberless alloy systems.

Briefly, the original duralumin theory stated that:

1. Age hardening depends on a considerable variation in solid solubility of the hardening constituent, it being higher at elevated temperatures than at atmospheric.
2. This constituent in duralumin is the compound $CuAl_2$.
3. Hardening is caused by the precipitation of $CuAl_2$ in some form other than atomic dispersion, and probably in a fine disperse in molecular, colloidal or crystalline form.
4. The hardening effect is considered to be related to particle size, a critical dispersion giving maximum hardness.

Meanwhile an enormous amount of work has been done on the problem. Other properties than hardness have been measured in various stages of the process. The influence of alloy composition, grain size, state of strain, nature of the heat treatment have also been studied, and the discovered facts cannot be explained entirely by the simple theory outlined above. This is readily admitted by Merica (see his series of articles commencing in January 1935 METAL PROGRESS). New hypotheses postulate a two-stage action; one view put forward by Cohen visualizes a preliminary "knot" formation in advance of actual precipitation; another by Gayler is that preliminary diffusion of insoluble atoms must occur to planes about which precipitation proper will ultimately take place; still another by Fink and Smith ascribes the first hardening to localized plastic deformation caused by the internal strains set up during quenching.

Whatever the theoretical explanation, the importance of age hardening to industry is far reaching. There is scarcely need to refer to the enormous uses of *(Continued on page 412)*

REVIEWS OF RECENT BOOKS

Steel Analysis

SAMPLING AND ANALYSIS OF CARBON AND ALLOY STEELS. Methods of the chemists of the subsidiary companies of the United States Steel Corp. Third revised edition. 356 pages, 6x9 in., 19 figures. Reinhold Publishing Corp., New York. Price $4.50.

Reviewed by LEWIS F. HERRON

This is an up-to-the-minute reference book on steels, and deserves a place on the active bookshelf of any chemist who analyzes steel, primarily because of the simple, logical description of methods.

A chapter devoted to sampling explains procedure in obtaining representative cuttings from all types of sections, and the sketch of a rod and wire sampler should be of great assistance to one who has much of this material to prepare for analysis. (The poorly drawn sketches, by the way, are the one obvious defect in the book.)

Some quick qualitative tests, as well as complete quantitative methods for all the elements which may be found in steel, are given. The outstanding feature of the book is the special consideration given to that part of analysis so necessary to accurate results, namely, chemical separation. Most recent methods, as well as the older procedures, are given.

In all methods presented, the causes of inaccurate analysis are carefully pointed out. As an example, low results on chromium as determined by the perchloric method are shown to be due to volatilization as chromyl chloride, as well as to incomplete oxidation. An interesting method for separation by this same volatilization is given, and the use of a new indicator for chromium and vanadium is described which should largely eliminate the personal element.

Interesting new methods for the determination of molybdenum and aluminum are given, and the determination of sulphur by combustion is exhaustively treated in the appendix.

It is probable that some very rapid methods of estimation used for preliminary samples have been withheld, but in all other respects, the book indicates a sustained effort on the part of the committee to amass, investigate, and standardize procedures for every conceivable requirement of ferrous analysis.

Iron-Nickel Alloys

THE ALLOYS OF IRON AND NICKEL; VOL. I—SPECIAL PURPOSE ALLOYS. By J. S. Marsh. 593 pages, 6x9 in., 290 figures. Published for The Engineering Foundation by McGraw-Hill Book Co., New York. Price $6.

Nickel, being one of the oldest, the most important and widely used of all constituents in alloy steel, has naturally been the subject of an enormous technical literature. Mr. Sisco and his staff at Alloys of Iron Research therefore despaired of reviewing all of it within one volume, so they divided the material, this volume containing extensive chapters on the iron-nickel and iron-carbon-nickel structural diagrams, the magnetic alloys, the alloys of unique thermal characteristics, and the ternary iron-nickel-chromium alloys wherein nickel predominates. Volume II will confine itself to the engineering alloy steels (nickel up to 5%) and the nickel cast irons.

The Editor is somewhat puzzled how best to arrange for a review. The subject matter is so highly specialized that a specialist should do it, but the ones whose names come to mind are listed in the book as either having contributed to the work or having already read and criticized the manuscript. That eliminates the experts! This non-expert, in looking about for a dog to beat, remembers that the organization and operations of Alloys of Iron Research have been described often enough in reviews of the earlier monographs to remove this from the list of suitable topics for discussion. The last refuge of the critic (belaboring the publisher for poor bookmaking) is also closed, for

McGraw-Hill and The Maple Press are producing this series of technical books whose uniformly high quality sets a new standard in America.

One of the fundamental aims of the whole program of Alloys of Iron Research is to discover important gaps in present recorded knowledge. When data were assembled on the tensile and other mechanical properties of the iron-nickel alloys, very uncertain and at times contradictory data appeared between 12 and 25% nickel. This fact, becoming known to Messrs. Pilling and Brophy of Bayonne Research Laboratory, International Nickel Co., inspired them to prepare a series of alloys within this range for systematic study, and the extensive results, now published for the first time, mark this volume as an important innovator, and future Alloys of Iron Research Monographs may be expected to be *more* than critical digests of published literature, and contain an increasing proportion of newly discovered facts supplied especially by cooperating researchers at the suggestion of the editorial staff.

Another method of treating lacunae appears in Chapter III on the iron-carbon-nickel constitutional diagram. The literature contains practically nothing about this except in the small corner occupied by the engineering alloy steels. In former volumes of this series such a situation would be noted and the matter suggested as a good subject for future investigation. In this volume Mr. Marsh goes further. He notes that the "lack of a diagram is felt slightly, if at all, by technology", but the opportunity to develop a hypothetical diagram consistent with the data which are available and the theoretical requirements is too good to refuse. The student of Marsh's previous book "Principles of Phase Diagrams" may now take a post-graduate course in the construction of ternary diagrams, for the brilliant author proceeds to develop the ternary iron-nickel-carbon system from almost non-existent data — nothing less than a *tour de force!*

E. E. T.

Manual of Heat Treatment

STEEL AND ITS HEAT TREATMENT (VOL. II, ENGINEERING AND SPECIAL PURPOSE STEELS) by Dennison K. Bullens. Fourth Edition, revised by the metallurgical staff of Battelle Memorial Institute. 491 pages, 6x9 in., 189 illustrations. John Wiley & Sons, New York. Price $5.00.

Reviewed by GORDON T. WILLIAMS

Enough was said of the circumstances leading up to this revision of the much-used "Bullens" in the review of Volume I in December's METAL PROGRESS. Let it here be emphasized that in its new format it strives to give a philosophy of steel selection and application, and I think succeeds well in that direction. The same things that make the Alloys of Iron Research Monographs good (and bad) are here — the "correlated abstract" and copious notes, details on steels outmoded or available with difficulty; much German data of questionable value in view of the essential differences in steel making; insufficient weighting of data and viewpoints; splendid bibliographies.

Because the book is promoting a system of thought it will probably miss its proper audience. The ones who most need this book, the ones who used to use "Bullens", are non-scientific, even non-metallurgical. They are not interested in systems of metallurgical thought. And I do not think a designer, for example, is going to *study* both these new volumes thoroughly so he can in future pick one of them up and understand an isolated section then of interest to him. In other words, the man who wants to know "what steel to use for this shaft" is going to have trouble finding out — he will end up by using the new "Republic Alloy Steels" or "USS Carilloy Steels" handbooks. Likewise the heat treat man, handed a given steel, is not going to uncover the treatment here in a hurry.

True, such judgments should not be made off-hand — but they usually are and will be in the great number of cases in the hundred thou-

sand small shops with little or no metallurgical control. Those are the places where a good handy book will be useful, rather than in the few hundred well-staffed plants with a materials engineer!

Under the circumstances, the next edition could do something more important than correct the defects noted in the first volume. By eliminating about 30% of the text as either repetitive or less necessary, by revising the remainder so it can be used for quick reference rather than for study and a guide for further reading, the whole matter could be compressed into a single volume and fill the need, still unsatisfied, of a book for the non-metallurgical man who occasionally must make an important selection of steel and decide on its treatment.

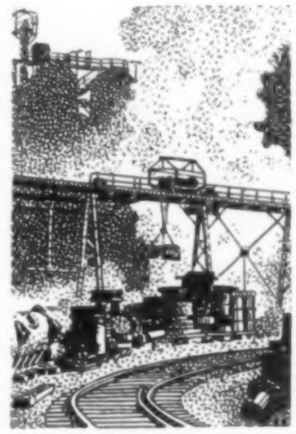
Pig Iron Smelting, American Style

Blast Furnace Practice, by Ralph H. Sweetser. 356 pages, 6x9 in., 123 figures. McGraw-Hill Book Co., New York. Price $4.00.

Reviewed by Walther Mathesius

I have read with considerable interest this recently published book about operations which for a long time occupied my working days, and while my comments must be brief, the brevity should not reflect on the excellence of the book, but rather on the time and energy of the reviewer!

It has been many years since an American author has compiled in book form an outline of pig iron blast furnace construction and practice. I have in mind such works as "The Blast Furnace and the Manufacture of Pig Iron" by Forsythe, and "Principles, Operations and Products of the Blast Furnace" by Johnson. While the fundamental process of pig iron smelting has not changed appreciably since publication of these books about 20 years ago, yet there have been many refinements of the art, and great improvements in furnace design as well as auxiliary equipment. Mr. Sweetser has adequately recognized this need. His contribution is therefore timely, and I believe this book will be welcomed by the men actively engaged in the manufacture of pig iron, as well as by students and others interested from a business angle.



Ultra-Light Metal

Magnesium and Its Alloys, by J. L. Haughton and W. E. Prytherch. 100 pages, 5½x8½ in., 60 figures. American edition by Chemical Publishing Co., New York. Price $1.50.

Reviewed by Louis W. Kempf

This book is reprinted for the American market from the original published in 1937 by His Majesty's Stationery Office, London. No changes have been made in reprinting; even the paging in the present edition is identical typographically with that of the original. (One important exception may be noted in that the original is still available at a price of 2s. 6d. per copy as compared with $1.50 for the present edition.) Some changes would have been advisable; for example, the unit in which the tensile properties are reported might better have been the "pounds per square inch" generally utilized in this country rather than the English "tons per square inch".

To American readers interested in the magnesium industry, the book will be useful primarily for the original data it contains on the mechanical properties of various members of magnesium alloy systems. These data are the result of investigations performed at the British National Physical Laboratory under the auspices of the Department of Scientific and Industrial Research. Those portions of the book which deal in a general manner with protection against corrosion and fabricating procedures are not sufficiently detailed to be of much use to those engaged in the commercial production of magnesium products. The principles enunciated in these portions should be useful, however, to those desiring a general knowledge regarding the uses and limitations of the metal.

Thirty-eight pages are devoted to the constitution of alloys of magnesium. This portion of the work will be of use primarily to those engaged in research on magnesium and magnesium alloys.

It will be noted that the various portions of the book probably will appeal to widely different groups of individuals. It is doubtful, however, if any one group of specialists will be satisfied with the limited treatment of the specific portion of the subject in which it is interested. A comprehensive book on magnesium is yet to appear.

AUSTEMPERING OF S.A.E. ALLOY STEELS NOT ALWAYS ADVANTAGEOUS

By Peter Payson
Chief Research Metallurgist
and Walter Hodapp
Metallurgist, Research Laboratory
Crucible Steel Co. of America
Harrison, N. J.

THE EXTREMELY VALUABLE work of E. C. Bain and E. S. Davenport on the transformation of austenite at constant subcritical temperatures has led to the discussion of a method of heat treatment called "austempering". This treatment, which consists of quenching plain carbon steel from a temperature well over the critical into a bath at a temperature between about 350 and 600° F. and holding it there until it is completely transformed, has aroused considerable interest, because it has been reported that the resulting structure has a better toughness at a high hardness than that found in the same steel quenched into water and tempered to the same hardness. The data so far published have referred only to plain carbon steels, and they have emphasized that the treatment is good only for quite small sections, up to about 0.150 in. diameter. Restriction to small sections is because of the necessity for cooling the steel rapidly through the region of rapid transformation rates — the so-called "nose" of the transformation curve — in order to avoid transformation in the steel at this higher temperature.

It might be well to digress from our main theme for a while, at this point, to discuss this size limitation, which can best be understood in terms of hardenability. It is well known that when a piece of plain carbon toolsteel, say 1 in. diameter, is quenched into cold brine from a heating temperature of 1450° F. only an outer rim perhaps 10/64 in. in depth will be fully hard martensite, the center of the section being fine pearlite (or lamellar troostite) with a Rockwell hardness number of about C-40. At the inner edge of this "case", there is a mixed structure of martensite and fine pearlite (or lamellar troostite). From the adjoining sketch, adapted from the work of Bain and Davenport, we know that the outer rim, because of its rapid cooling through the range of 1100 to 900° F., avoided transformation in this upper region of the transformation temperature-time curve where the transformation of austenite proceeds very rapidly — a matter of about 5 sec. — and transformed only in the lower region near room temperature where martensite is formed equally rapidly. This is noted by dotted line marked "surface". The center of the bar, because of its much slower rate of cooling, transformed completely in the region between t_1 and t_2 on the line marked "center", a region of very rapid transformation above 1000° F., the product of transformation being fine pearlite (or lamellar troostite). That part of the bar in the zone of the inner edge of the "case", because of its intermediate rate of cooling, transformed

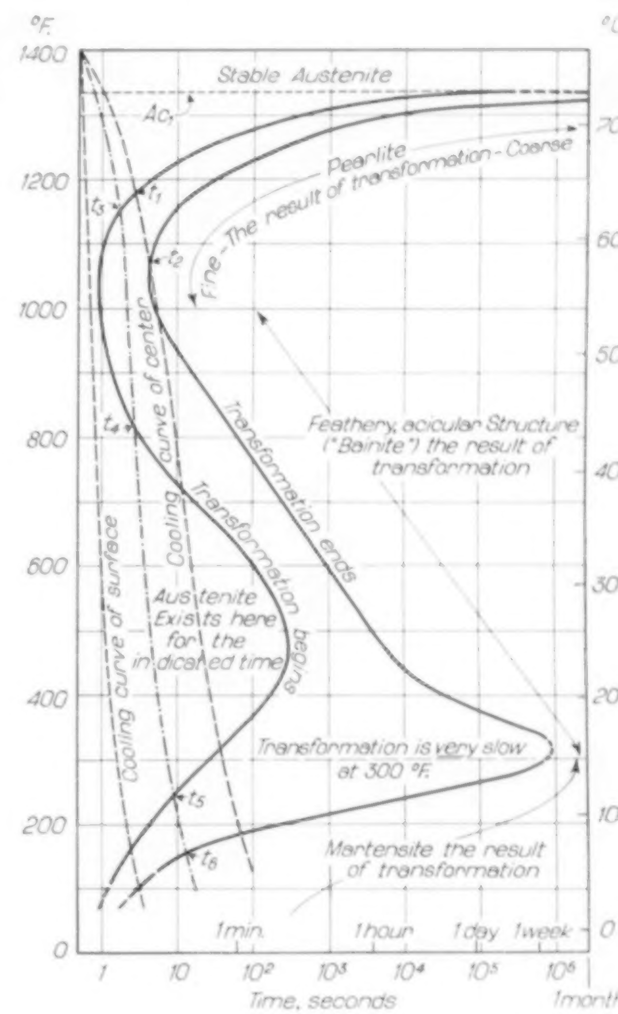
partly in the upper temperature region of rapid transformation between the temperatures marked t_3 and t_4 and partly in the lower temperature region of rapid transformation (t_5 to t_6) and consequently the structure contains a mixed product of fine pearlite (or lamellar troostite), and martensite.

If this 1-in. bar of plain carbon toolsteel is quenched in oil, instead of in brine, from the same heating temperature, or even from a somewhat higher one, its rate of cooling even at the outside of the bar is not sufficiently rapid to avoid transformation in the high temperature region of rapid transformation, around 1000° F. The cooling curve of the surface will be something like the one marked "center", and the bar after being quenched in oil will consist of fine pearlite (or lamellar troostite) throughout its section — the pearlite at the center being a little coarser since the product of transformation above 1000° F. is fine pearlite (or lamellar troostite) of increasing lamellar thickness and decreasing hardness as the temperature of transformation rises toward Ac_1. The Rockwell hardness number across the section of the 1-in. bar of carbon toolsteel quenched in oil will be about C-40, just as at the center of the 1-in. bar quenched in brine because the mechanism of transformation is the same in both cases.

Conditions After Oil Quenching

When the cross-section of the bar is decreased, the cooling rate at the center increases rapidly for a cold brine quench, but much less rapidly for an oil quench. Thus when the bar is decreased in diameter from 1 in. to about ⅝ in., it may harden clear through to the center in a brine quench (which means that the cooling rate at the center has been fast enough to avoid transformation at the 1000° region) whereas when the ⅝-in. bar is quenched in oil, it may again have a hardness number of about C-40 at the center (which means that the cooling rate at the center of the bar was still not sufficiently rapid to avoid this transformation). If we continue to decrease the size of the bar, we will eventually reach a size — at about ¼ in. or less — which will cool sufficiently rapidly at the center in an oil quench to avoid any high temperature transformation, and form only the low temperature transformation product which is martensite.

In the austempering process, the steel is quenched into a bath at some temperature higher than 350° F. It is essential that the steel be cooled sufficiently rapidly to the temperature of the quenching bath, to avoid transformation into fine pearlite (lamellar troostite) at or about 1000° F. Since the cooling rate of steel, when quenched into a bath at 350° F. or higher, is slower than the cooling rate of steel quenched into an oil bath at room temperature, it may be taken as a general rule that the maximum size

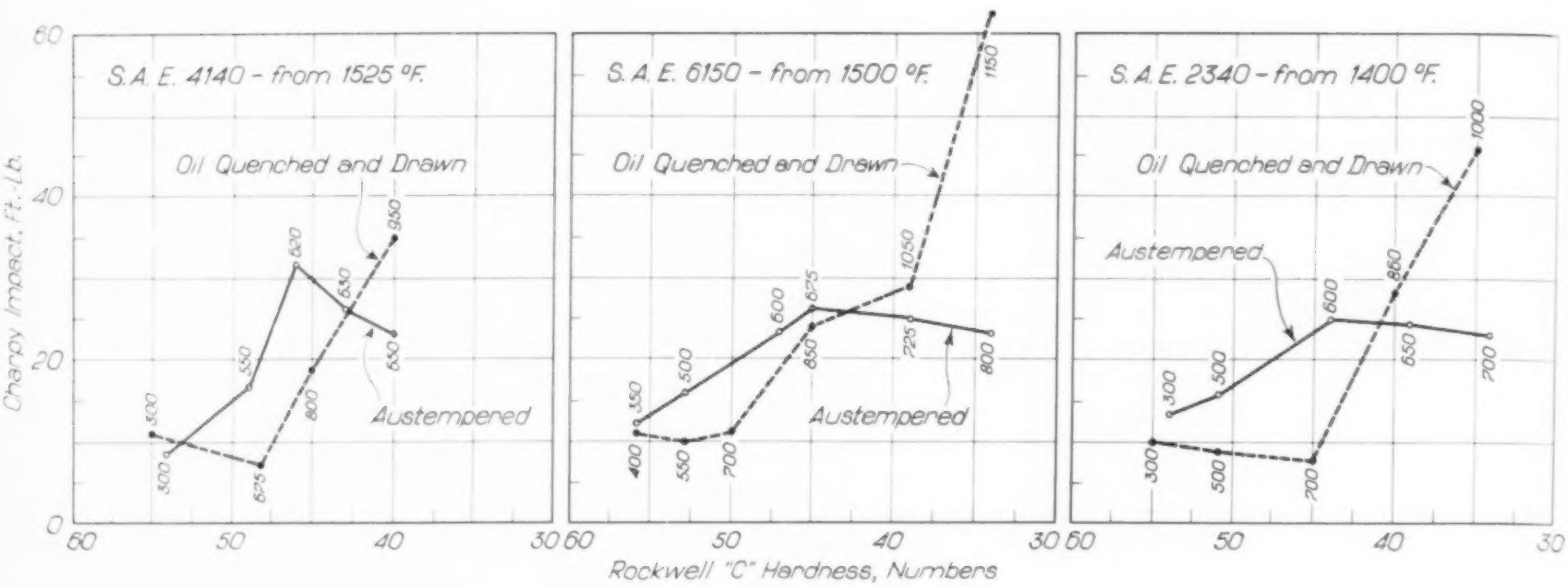


"S-Curve" (Adapted From Bain and Davenport's Work) Showing the Transformation of a Bar of Eutectoid Carbon Steel. Full curves show the time for beginning and ending of transformation of austenite suddenly quenched to the indicated temperature and held there. Approximate cooling curves are for a 1-in. bar brine quenched. Time is plotted logarithmically.

of steel that can be satisfactorily austempered is smaller than the size that can be fully hardened in an oil quench.

It should now be clear why austempering of plain carbon steels must be confined to small sections.

There are many steels, however, other than the plain carbon steels, which we know may be



fully hardened in fairly large sections by a quench in oil. Among these are many alloy steels used for structural parts in automobiles, airplanes, and machine tools. Since the austempering treatment is reported to give plain carbon steels a better combination of toughness and hardness than the conventional heat treatment, it seemed of interest to determine the effectiveness of this treatment for alloy steels, where the limitation of size would be less severe. In order that the data should be in units which are familiar, and therefore comparable to established data, the tests reported here were made with V-notch Charpy pieces machined to the dimensions shown in Fig. 10, page 48, in Metals Handbook 1936 edition.

Steels selected for this investigation were several S.A.E. alloy steels of about 0.40 to 0.50% carbon, such as are ordinarily hardened in oil. Their analyses are given below:

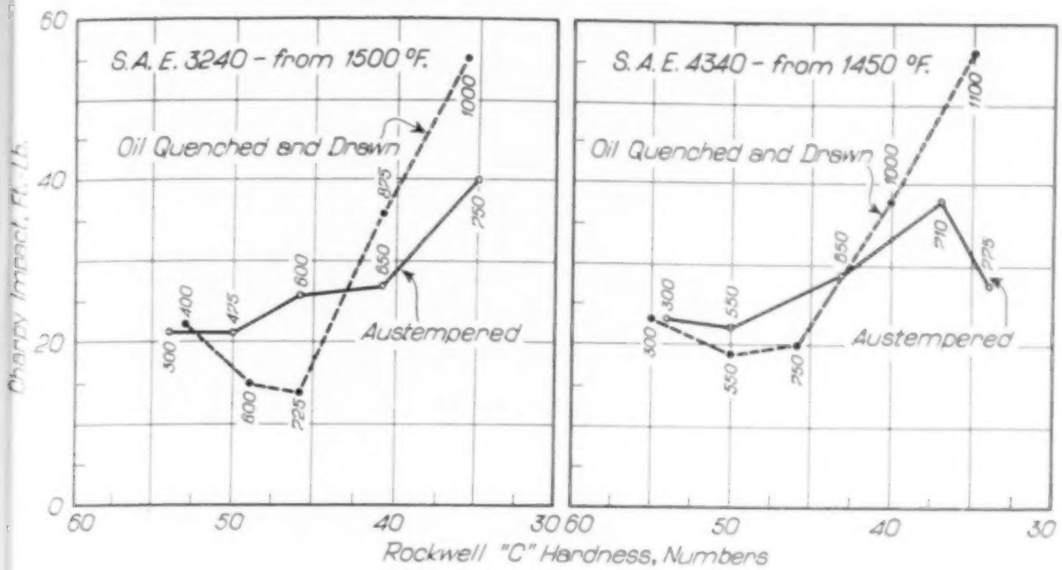
Analyses of Steels Tested

Grade	C	Mn	Si	Ni	Cr	Mo	V
S.A.E. 4140	0.40	0.78	0.17	....	0.96	0.29	....
S.A.E. 6150	0.51	0.95	0.19	....	1.03	....	0.20
S.A.E. 2340	0.38	0.58	0.29	3.11	....	....	....
S.A.E. 3240	0.41	0.48	0.27	1.68	1.05	....	....
S.A.E. 4340	0.37	0.47	0.21	1.80	1.05	0.23	....

As a preliminary test to determine whether these steels could be austempered successfully in a Charpy test piece, samples of each of the steels, 0.394 in. square by about 1 in. long, were heated to the conventional temperatures for hardening them, then quenched into a salt bath at 600° F., held here for 30 sec., and then quenched in water. The 30-sec. holding time was used because it had been found that the center of a piece of this size required about that time to cool from about 1450 to 600° F. when it was quenched into a bath at 600° F. The data in the second table indicate that only a small change had occurred during cooling from quenching temperature to bath temperature, and that therefore standard Charpy size test pieces of these grades could be austempered satisfactorily.

Since Davenport and Bain had shown in their S-curve (transformation temperatures versus time) that the completion of transformation in plain carbon steel at temperatures between about 300 and 600° F. might take a long time, further preliminary tests had to be made to establish whether these alloy steels could be transformed completely at low temperatures in a reasonably short time. Accordingly, samples of all these steels were quenched from appropriate heating temperatures into baths at temperatures from 800 down to 300° F., held for 5, 15, 30 and 60 min. at each temperature, and then quenched into water. Hardness tests on these samples showed that all grades were completely transformed in less than one hour at all temperatures from 800 to 300° F., and in most cases in less than 30 min.

It was now established that austempering these grades in Charpy test pieces was entirely feasible. A series of such pieces were then heat treated by the conventional oil quench and temper, as well as by the austemper method. Temperatures for tempering after the oil quench, and for austempering, were selected so the test pieces covered a range of hardness from about Rockwell C-35 to C-55. The test



Relation Between Charpy Impact and Hardness Numbers After Austempering 1 Hr. at Temperatures Noted (Followed by Air Cooling) and After Quenching in Oil and Drawing Back 1 Hr. at Temperatures Noted (Followed by Air Cooling). All samples were held 45 min. at the heating temperature before they were quenched

pieces were then broken on a standard Charpy machine of 240 ft-lb. capacity. Data obtained are plotted in the curves.

In their discussion of the superior toughness of austempered plain carbon steel when compared with quenched samples tempered to the same hardness, Davenport, Roff, and Bain refer to the presence of micro-cracks in the water quenched pieces as the probable cause of the inferior toughness. We believe there is very little likelihood that micro-cracks occur in the oil quenched pieces of these alloy steels. The superior toughness of the austempered samples treated to hardnesses within the range of about C-44 to C-52 therefore requires some other explanation.

Comparative Hardness of Charpy Test Pieces Quenched in Cold Oil and in Molten Salt at 600° F.

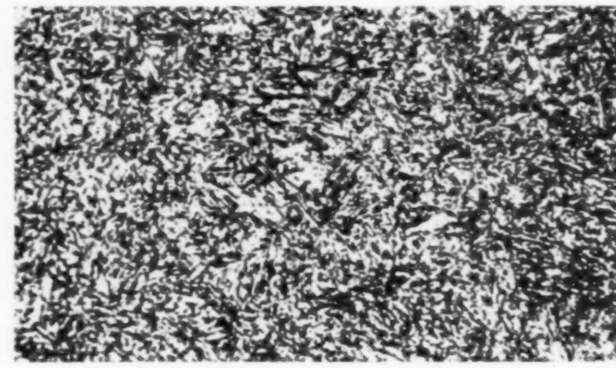
Steel	Quenched From	Oil Quenched Hardness	Held 30 Sec. at 600° F.	
			Hardness	Structure
S.A.E. 4140	1525° F.	C-55	C-48 to 53	10% ferrite 10% bainite 80% martensite
S.A.E. 6150	1500	C-59	C-53 to 56	martensite
S.A.E. 2340	1400	C-56	C-47 to 54	martensite
S.A.E. 3240	1450	C-56	C-52	martensite
S.A.E. 4340	1450	C-56	C-55	martensite

Our curves of toughness versus hardness for the conventionally oil quenched and tempered samples show breaks in the hardness range corresponding to tempering temperatures from about 400 to about 700° F. This low toughness region has been known for a long time, and it has been accepted generally that it is caused by the breakdown of retained austenite which accompanies the low temperature tempering of oil quenched steels. The austempered steels, on the other hand, show the expected increase of toughness with decrease of hardness in the range from about C-55 to C-45, and in some cases down to C-40 or lower. In the hardness region between about C-44 and C-53 therefore, the austempered steels have a definite advantage in toughness. They also would undoubtedly have an advantage in regards to minimum distortion and size change.

In the region of highest hardness — that is, the lowest tempering or austempering temperature — there is practically no difference in toughness. This is to be expected because isothermal transformation at about 300° F. is very little different in its mechanism from the low temperature transformations which occur during an oil quench.

That the conventionally oil quenched and tempered samples should increase in toughness with decreasing hardness is to be expected, once all the retained austenite is broken down, because the change which takes place with increasing tempering temperature is a continuous agglomeration of carbides causing a softening of the sorbite. The shapes of the curves of toughness versus hardness of the austempered steels, on the other hand, are at first glance quite surprising, because the toughness does not increase steadily with decreasing hardness. On second thought, however, it does not seem unreasonable that some products of transforma-

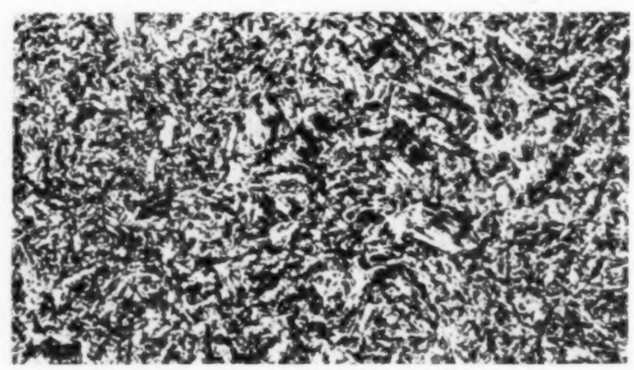
Microstructure of S.A.E. Steels Austempered to Moderate Hardness Is Almost Indistinguishable From Same Oil Quenched and Tempered to Same Hardness. Magnification 1000 ×; nital-picral etch

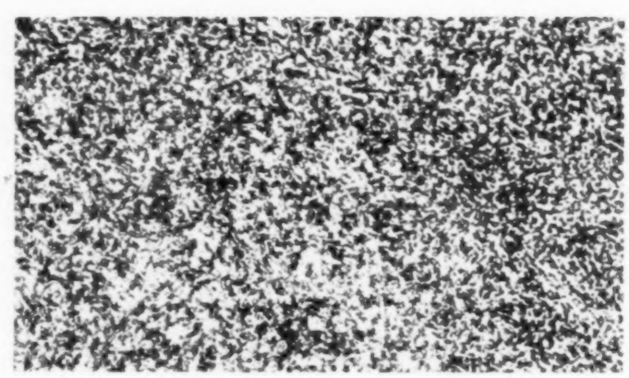


Above: Oil quenched, tempered at 800° F. Rockwell C-45; Charpy 19 ft-lb.

S.A.E. Steel 4140, heated to 1525° F.

Below: Austempered at 620° F. Rockwell C-46; Charpy 32 ft-lb.

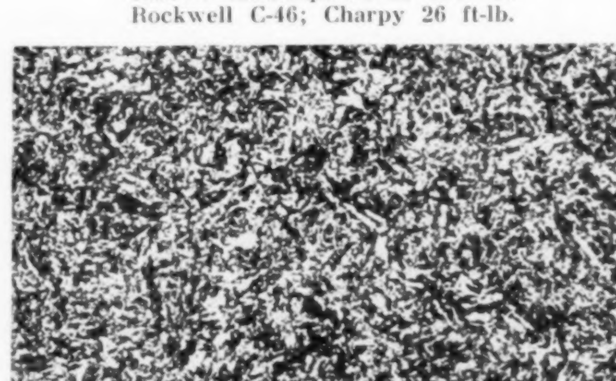




Above: Oil quenched, tempered at 725° F. Rockwell C-46; Charpy 14 ft-lb.

S.A.E. Steel 3240, heated to 1500° F.

Below: Austempered at 600° F. Rockwell C-46; Charpy 26 ft-lb.



tion may have a greater toughness for a given hardness than others, since we know that the products of transformation at various sub-critical temperatures are not necessarily in a continuous series which increases in toughness with decrease in hardness. For example, in a plain 0.80% carbon steel, the product of transformation at 1000° F. is very fine pearlite with a Rockwell hardness number of C-40 and a Charpy value of 7 ft-lb.; when the transformation occurs at about 1200° F. the product is a pearlite of medium coarseness with a hardness number of C-28, but the impact value is still about 8 ft-lb.; and when transformation takes place at 1300° F. the product is a relatively coarse pearlite with a hardness number of only C-11, but this softer structure also has a much lower impact value, namely 3 ft-lb.

When we examine the structure of these alloy steels, however, we find no clear cut differences to account for the differences in the impact values. Indeed, it is almost impossible to distinguish some of the austempered structures from the oil quenched and tempered structures. Accompanying micrographs illustrate the difficulties in distinguishing these structures. It would be unwise for us, with our knowledge of the history of steel metallography, to state that there are *no* differences among these structures; it is better to say that with our present technique, we cannot recognize any.

This study of austempering appears to offer some interesting possibilities for obtaining improved combinations of high hardness and toughness in the familiar S.A.E. steels. As yet we know of but a few commercial applications of this heat treatment. The limiting sizes in the various alloy steels still have to be determined. Some grades will be found to be less restricted in size than others, and it is to be expected that the steels with the greater hardenabilities could be austempered in heavier sections. Further investigations along these lines certainly seem warranted.

However, for alloy steel parts which are to be used with a hardness number under about C-42 — and this covers most of the S.A.E. steels used at present — there is no advantage in the austempering treatment; the conventional oil quench and temper treatment is definitely superior to the austempering treatment when maximum toughness is required.

HARD FACING OF OIL WELL DRILLING BITS WITH CAST TUNGSTEN CARBIDE

By Charles H. Shapiro
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PRIOR TO 1923, bits for drilling soft geological formations were redressed, that is resharpened, by forging. Dull bits were heated in a slot furnace or blacksmith's forge, after which each of the blade wings was successively hammered to a tapered edge, formed and trimmed to the characteristic fishtail shape. Cutting edges were then "tempered"; each bit dresser claimed a secret hardening process or "sharp, experienced eye" which made his bits the "hardest, with never a broken corner"! Considering the equipment he worked with, a surprisingly good redressing job resulted.

One can readily see that trimming and shaping the cutting edges wasted material and severely shortened the life of a bit. Many a fishtail bit too short to use could be seen hanging from derrick lines acting as counterbalances or deadweights. Many, with their costly machined threads, found their way into junk heaps or were "seeded" in the bottom of slush pits. New and more efficient dressing methods were being sought, and the oxy-acetylene torch and metal rods of new compositions seemed to offer great promise.

The very earliest attempts to surface fishtail bits with an acetylene torch used cast iron or toolsteel weld rod — metals, which, though not the most efficient, were the forerunners of materials which had very desirable qualities. Further development produced those in general use today and which, from our present viewpoint, can be considered eminently successful. These early rods, used for surfacing materials, were followed by a special type of rod made up of a powdered element or alloy, which, together with an ordinary mild steel rod, was encased by a thin, closed strip or tape of low carbon steel. This was the first successful overlay and, because it became hard on deposition, was termed "self hardening". All the old-timers remember this rod, and even today it finds applications in many fields.

Claims first made for it were quite out of reason, and it was soon followed by another alloy, of chromium, tungsten and cobalt cast in the form of a welding rod. Technique of application was quite similar to that for materials previously deposited by the oxy-acetylene torch. This alloy, stellite, had a higher resistance to abrasion than had the other hard surfacing metals of that day, and its use all but displaced the old method of dressing and tempering. The field was soon flooded with other homogeneous hard surfacing rods, some quite similar, many containing different elements in varying quantities, but the original material,

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along with a composition made by another manufacturer, was superior to the others and remained in widespread use.

In the main, the advantages of a welded-on overlay when compared with the tempering method were greater dependability, longer life, and increased footage drilled. Drilling operators had long desired bits with these characteristics, even at considerably higher cost.

Following these hard surfacing alloys came the introduction, during 1927 and 1928, of diamond substitutes composed principally of the tungsten carbides. Tungsten carbide, in irregularly shaped pieces or slugs, was at one time selling for $320 a pound. Despite this high cost, its advantages became apparent, and it was then necessary to produce this new metal in quite large quantities, which in turn reduced its selling price. Various other forms of this material, having distinct advantages in definite applications, were soon afterward developed, the most important of these being thin-walled tubes or sheaths filled with crushed and graded particles. This tube could be handled as easily as an ordinary welding rod, and the metal of the tube after deposition acted as a binding material, fusing itself to both the basis metal and the tungsten carbide grains. Composite or amalgamated rods, made by previously melting low carbon steel onto graded, crushed, irregularly shaped tungsten carbide granules so as to form a rod or stick, act similarly to tubes filled with crushed metal.

Tungsten carbide was not a newly discovered material. It was in 1927, however, that a clearer understanding of its practical application and possibilities of combinations with other materials was reached. About this same time methods of manufacture on a quantity basis were perfected. Another important discovery was the advantage of adding or combining carbide with other alloy materials as metallic binders.

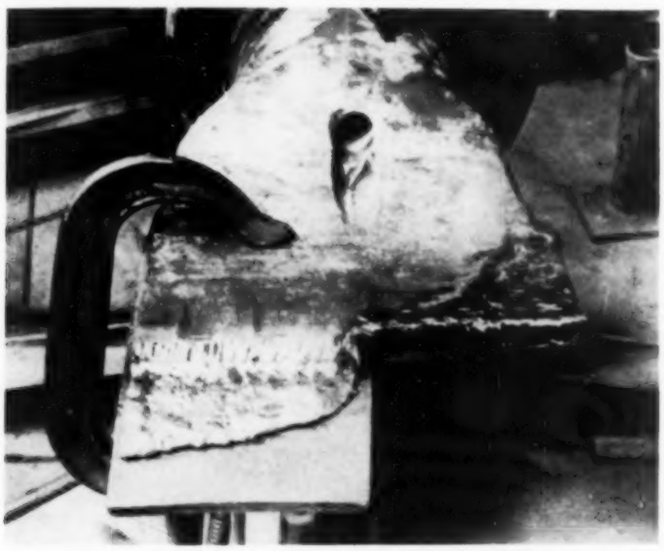
Tungsten carbides, as used today, fall into two general classifications; sintered carbides used mainly for metal cutting, and cast carbides used as hard surfaces for cutting edges of earth boring tools, as well as other applications for resisting wear and abrasion. The sintered carbides are relatively high in cost; the cast carbides, being manufactured by a fairly simple melting procedure, find wide use.

Cast or fused tungsten carbide can be purchased in pieces (slugs) with special or standard shapes. These are termed inserts. It is also available in broken, irregular pieces of medium size called peas. It may also be purchased as composite metal, tube metal, or in bulk — crushed, graded and numbered according to the mesh screen through which it will pass.

Hard Facing Materials Include Inserts or Slugs (Lower Left), Amalgamated Rods (Top Left), Strips (Left Center), Homogeneous Alloy (Right Center), and Thin Walled Steel Tube Filled With Granules (Lower Right Is One Split Open)

Its early application was only in the form of slugs. These were set on the cutting blades and covered with some homogeneous hard metal. Today this metal is applied in two forms on the same wing of a fishtail bit. The inserts are set partially into the steel surface after melting a spot or grinding a groove to accommodate them. After setting, the inserts and surface adjacent are covered with tube or composite metal. A detailed account of the technique for repairing and rebuilding a worn bit will follow.

A correctly designed fixture or holder is indispensable, arranged so that the welder can turn, change the level, gage and build up the worn bit to a true center



with the axis of rotation. Bit holders are on the market that are marvels in their simplicity and efficiency. A further requirement is a grinder for preparing surfaces for welding, and for the grinding of cutting and reaming edges to exact dimensions.

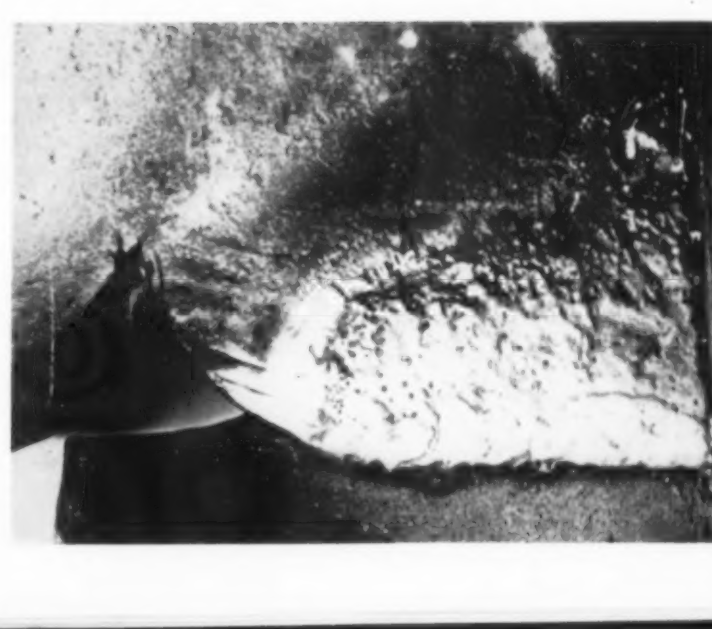
In building up a worn blade, it is necessary first to weld out from the worn or cutaway edge, building up with a material that has physical characteristics approximating the original base metal. Deposits from a rod which will contain from 0.35 to 0.45% carbon are most suitable. In order to control this molten metal, a copper back-up template or form is made of ¼-in. copper plate, curved slightly to the shape of the bit and the desires of the welder. Carbon blocks have been and are still used by some operators in place of copper forms.

After the worn fishtail bit is mounted in the fixture, the old, remaining hard metal should be "washed off" with a cutting torch. The cutting and reaming edges of the bit are then trimmed, ground, and conditioned for the weld deposit to follow.

The edge of the trimmed wing, and the adjacent area are first brought to a dull red heat, approximately 1300° F., by heating with the acetylene torch. This preheat prevents possible heat checks. One blade is built up at a time. The template is fastened to the bit wing by U-clamps, having spring action. The surface of the copper plate is then marked off by means of a soapstone stick to the size and dimension of blade required. The tungsten carbide inserts are laid out upon the surface of the plate in the pattern desired. The wing or blade of the bit is then built out to its original shape. The inserts are first lightly covered. The bit is then turned over, the copper template removed, and steel applied. Steel is deposited until top and bottom faces of the blade are completely rebuilt to desired thickness and level.

The surface is then covered with either tube metal or composite rod with a size of grain as desired. In use the crushed carbide acts as a wear resisting surface against impingement of slush. It also becomes the cutting edge as well as a protection for the inserts.

Steps in Reclaiming a Fishtail Bit. Top, the old bit has been trimmed with a cutting flame and the inserts laid out in proper position on copper backing-up plate. Top middle, inserts are lightly covered with steel welding rod. Bottom middle, steel has been deposited on both sides to desired thickness plus grinding allowance. Bottom, close-up of finished blade ready for normalizing, covered with hard facing



The dressing of the reaming edge is also of prime importance, for which bit dressers use tube metal or amalgamated rod. The grain size is usually medium to fine. Reaming edges are built up somewhat beyond the desired gage with welding rod followed by a thinner deposit of tungsten carbide. This reduces the tendency to flaking. Grinding then brings the bit exactly to gage.

After building up and surfacing the first wing, the same operations are successively repeated on the remaining blades of the bit.

New fishtail bits and detachable blades are hard surfaced by a more or less standardized procedure. The blade is properly cleaned and preheated to dull red (1300° F.). The spot desired for setting the insert is heated by an oxy-acetylene flame until it melts in an area somewhat larger than the size of the insert. Without letting the spot cool, the end of a mild steel rod is heated until it "sweats" and touched to a hot insert and the two further heated until they adhere. The hot insert is then submerged to the desired depth into the molten pool of base metal, and positioned. The torch is removed; the spot solidifies, and the attached rod is melted from the hard metal piece. These steps are repeated until all inserts are properly set, each in its desired position. Composite rod or tube metal of desired grain size is then laid down, after a surface retouching, as a facing over the entire hard surfaced section of the blade. Following this, reaming edges are faced with crushed carbides.

Another procedure, followed extensively, eliminates puddling. Instead, slots or grooves are ground in the new blade to accommodate the inserts, which are then bound by properly flowing in mild or high tensile steel rod. The pieces are entirely covered and the grooves completely filled. The surface, as in previous cases, is afterward covered with the desired size of crushed metal.

Correct hard-setting practice calls for a flame adjusted to an acetylene excess, reducing in character. The inserts should be spaced approximately 3/8 to 1/2 in. apart and in positions as directed by experience. The position of the inserts on the blades will control the condition of the worn edges. Blades set so that the inserts in them are lined up at equal radii will show a "fingering" type of wear. Those spaced so there is no "tracking" will wear to a flat edge. Inserts should be set back slightly over 1/8 in. from the cutting and reaming edges, in order to allow for subsequent grinding to sharp taper.

While there are a great many built-up bits that receive no treatment following the welding procedure which have given good field service, the author strongly recommends that the welding operation be followed by heat treatment of some kind. A simple treatment and one which would greatly benefit the toughness consists in normalizing from 1550° F. (heating followed by cooling in still air). Some oxidation of the exposed grain will occur, but this will not measurably decrease its efficiency. Many shops

Welding Jig Holding Bit. Inserts have been placed in teeth and wings, proper surfaces covered with layer of tube metal, and gage and reaming edges ground to proper diameters

accurately heat treat bits and welded parts, especially those which have no threads or surface measurements to maintain. Smaller pieces which can be set wholly within a furnace, such as wings of the detachable type, blades, core cutter heads, and cutter parts, are usually heated to correct temperature and oil quenched.

Cutters or cones for the roller bit type have their efficiency and life materially increased by hard surfacing at least one face of each tooth of the cutting members. The cutters which make contact with the wall of the hole have their gage or bevel edges also surfaced with hard metal.

Manufacturers of tungsten carbide have recently brought out tubes as small as 1/8 in. diameter. With this small tube it is a simple matter to hard surface tooth faces, even in the

small sizes. The size of grain packed in this tube is termed "30-40 metal" because only that crushed grain is used that will pass through a 30-mesh standard screen and will stop on a 40-mesh. A $\frac{3}{16}$-in. tube containing 20-30 metal is also well suited for surfacing rock bit parts. The main problem is to maintain sharp edges and slender teeth. All rock bit parts are heat treated after hard surfacing. Repairs to cutter cones are usually impracticable because the bearings are badly worn by the time the teeth are dulled. Another reason for refraining from welding such parts is that they are all heat treated, and repair welding will soften and render useless the area receiving the heat.

New Hard Metal Introduced

A new hard metal was recently introduced whose hardness is derived from crystalline chromium borides together with an unknown crystal "X". It is much lighter in weight than tungsten carbide, and is claimed to have a hardness of approximately nine on the Moh's scale, which is somewhat below the hardness of fused tungsten carbide. It is applied in the form of a paste made up of 100-mesh particles. The procedure — called "sweat-on" — consists in spreading about $\frac{1}{16}$-in. layer of paste on a clean surface with a spatula. After thorough drying, the torch flame will produce a glowing effect on the crystals after a particular temperature is reached. This indicates a surface sweating and slight rising of the shallow, molten surface, which completely encases each of the "X" particles. On deposition the manufacturer states: "The chromium boride crystals alloy with the base metal, while 'X' crystals permeate the mass as if held in an emulsion." Because of specific gravity, too much or too prolonged heating will allow the crystal "X" to sink below the base metal surface, causing it to lose some of its desirable properties.

Deposits are being made by "sweating-on" tungsten carbide crushed metal with the acetylene torch and are proving eminently successful. Crushed metal is also being applied by means of the electric atomic hydrogen process.

Most of the new type of fishtail bits, rock bits, hard formation core bits, as well as special types such as wire line and retractable bits, have inserted and replaceable slush tubes or bushings. These are used to direct slush fluid, as well as to restrict it, so as to get a jetting action on the cutting edge of the blade. Forceful jetting aids materially in keeping the cutting edge clean at all times and in all formations. The inside diameter of these bushings varies from $\frac{1}{2}$ to 1 in., and is subjected to high abrasion of the slush (thick mud). Special hard metal materials are therefore required. Here again one finds the homogeneous type of hard metals. The bushings are cast to required shape and set into position by oxy-acetylene or electric welding, using mild steel rods.

Because of the severe impact or hammering effect upon the cutting edge of a cable tool bit, necessarily applied because of its drilling action, considerable difficulty has been experienced with hard surfacing materials. Homogeneous type metals have only been partially successful. A measure of success comes from careful control of welding and treatment, and the use of fine-grained tube metal, applied in a layer not too thick. One of the hard metal manufacturers suggests a change in the form of the cutting end of the bit from the "chisel" to the so-called "hell diver" type of edge.

Treatment of Bit Ends

Both new and redressed (reforged) bit ends should be in the normalized condition and preheated before application of the high tensile steel undercoat. The end is then surfaced with hard carbide metal of 30-40 grain size. Carbide having grain size 80 mesh and finer can be used with considerable success, because the solution and alloying effect approaches a homogeneous deposit. A thin surfacing of this material should be comparatively free from "flaking" or "chipping". Another likely type of surfacing should be fine-grained tungsten carbide sweated on.

After hard surfacing, the bit end should be heat treated to restore the ductility of the base metal, by heating uniformly to 1550° F., followed by a cooling comparable to an oil quench. The bit should be withdrawn before atmospheric temperature is reached, so that the heat on the inside of the bit may work its way through the hardened section and thus have the effect of a drawing treatment.

Most hard metals are applied with the oxy-acetylene flame. Some hard surfacing procedures make use of both electric and oxy-acetylene welding. There are also some operators who resort entirely to the electric process; in such case the metals must have a surface protective coat, usually of an inorganic composition, to keep them from oxidizing during application.

NOTES ON CORRECT USE OF THREAD HOBS

By A. E. Hogarth
Engineer
Detroit Tap & Tool Co.

IN RECENT YEARS there has been an increasing use of ground-thread multiple-thread milling cutters or, as I will hereafter refer to them by the names in most common use, "thread hobs" or "ground-thread hobs". Little has been published about this efficient precision tool and its field of use has not been fully explored. It is one of the most efficient and accurate methods of producing threads, especially when large diameters are being threaded either internally or externally. The main reason for this is the extreme accuracy to which the pitch diameter limits of the thread can be controlled, the good lead and thread angle obtainable, and the smooth finish produced. Ground-thread hobs, because of their accurate lead and angle and their ability to mill a parallel thread, are widely used in the manufacture of thread rolling dies which, in turn, are used to roll threads on bolts.

Quality of production will, of course, depend to a large extent on the equipment in which the hob is operated, and the care given the hob during its life. Rigidity in the machine is necessary if a smooth and accurate finish is to be produced. Play or vibration must be eliminated as much as possible; otherwise a rough thread form marred with chatter marks will result.

A number of users have adopted the method of "climb cut milling", and while this is not altogether new, its possibilities have not been given much attention until quite recently. Owing to the deeper cut that is taken at the beginning of contact between cutter and work, the rubbing action which takes place in the conventional type of milling is eliminated, and therefore the tool will remain sharp for a longer period. To "climb mill" successfully, the milling machine must be in first class condition and of a design rugged enough to withstand the heavier cut without vibration.

Care of the thread hob is worthy of much consideration. Correct grinding of the flutes is of prime importance and should be done in a sharpening machine that will maintain the correct spacing of the flutes and the correct rake in the cutting face. (Rake or "hook" is the angle between the cutting face and a radial line from the center of the cutter. It is commonly expressed in thousandths of an inch that the cutting edge is off center when that edge is parallel to a line drawn through the center of the cutter. This figure is usually stamped on the hob for information of the resharpener.) It is important to use the right kind of wheel when sharpening thread hobs. For obvious reasons, it is well not to use a wheel with too coarse a grain or one that does not run true.

The number of threaded parts produced between grinds will depend on several factors such as the kind of material being cut, the type of hob used, the speed and feed, the number of teeth in the hob, and the length of the thread, but each threading job has its maximum production before the tool becomes dull, and the operator should watch this closely to obtain maximum life from the hob.

The manufacturer usually designs the cutter, for he can usually recommend the type of hob suited to the intended work. There are numerous designs on the market, and among them the shell type is used mostly for external milling and the shank type for internal work. The diameter and number of flutes depends largely upon the size of the work and the capacity of the machine and, especially in the case of internal threading, is selected so that two or more of the cutting edges are engaged on the work at the same time. *(Cont. on page 386)*

METALS USED IN STRINGED INSTRUMENTS

PIANOS, HARPS,

VIOLINS, GUITARS

By Marjorie Rud Hyslop
Managing Editor, The ⊕ Review
Cleveland, Ohio

ACCURACY and precision might facetiously be called the "keynote" of musical instrument manufacture. For quality of tone is a function of the quality of materials used and the care taken in their manufacture. The material responsible for the production of tone in the majority of musical instruments is some kind of metal or a combination of metal and wood, and its careful manufacture and fabrication are essential to the production of clear, full, musical notes.

Consider the piano, for instance. Most metallurgists know that piano wire is the highest grade of drawn and heat treated spring wire obtainable, but they do not know why such exacting physical properties are necessary. To understand this, it is necessary to know something about the construction and mechanism of the piano itself.

The standard number of strings in a piano is 230. For each of the eight or ten lowest notes there is one string to a unison. For the next 25 or so there are two, and for the remainder there are three. The highest strings are about 2 in. long and vibrate 4186 times per sec. The length is gradually increased in a ratio of 1:1.051 per note, or 1:1.875 for an octave, so the lowest bass string, vibrating only 27 times per sec., would thus be about 18 ft. long. Such a length is impractical even for a concert grand, however, and the wires may be shortened by increasing their weight, as will be explained.

Each wire is looped at its far end over a hitch pin, crosses the wooden bridge of the soundboard, passes over the bearing bar or agraffe, to limit the "speaking" length of the string (somewhat similar to a knife edge in a balance), and is held against slippage by passing around and through the tuning pin.

Wires must be strung at a high tension for correct tonal quality. Since this is usually 160 lb. or more per string for the bass section and 150 lb. for the treble sections, the total tension on the supporting structure is from 35,000 to 50,000 lb. It is obvious, therefore, that this frame must be strong and stiff.

The frame, or piano plate, as it is known, is of high strength cast iron. It consists of a "tuning pin plate" and a "hitch pin plate" connected by struts or compression members, all cast in one piece. It must be strong enough to withstand tension and torsional strains, and the bars must be rigid and ample in section to take compression loads. Design of the piano requires that the plate be light and uniformly thin, and perfectly flat so it will fit into the case without interfering in any way with the vibration of the wooden soundboard, and also so the tuning and hitch pin plates will fit securely and evenly over the plywood pin block. Too heavy a plate will spoil the vibrating qualities of the piano.

An iron which is reasonably soft as well as strong is necessary in order that holes for the tuning and hitch pins may be easily drilled, and the most suitable analysis shows about 2.5% silicon and less than 0.4% phosphorus. Piano plates are hand poured quite hot through five to seven large gates so that the metal will flow easily through the thin sections of the mold. After casting, they are sandblasted,

chipped and ground, drilled, and finally japanned, bronzed, and varnished.

Cast iron seems to possess the desired combinations of ease of casting and machining, size stability, freedom from creep under stress, and stiffness (high modulus of elasticity in compression). Most proposed substitutes are deficient in the two latter items.

Musical tone depends, of course, upon the wire itself — upon its length, thickness, tension, density and microstructure. High grade Swedish rod is used, a representative analysis furnished by the acoustic laboratory of American Steel & Wire Co. being 0.85% carbon, 0.35% manganese, 0.15% silicon, 0.025% max. phosphorus, 0.025% max. sulphur. After drawing the wire is heat treated to a tensile strength of from 300,000 lb. per sq.in. for the coarse sizes (0.035 to 0.067 in. diameter) to 390,000 lb. per sq.in. for fine wire (0.029 to 0.049 in.). It must possess toughness, elasticity, springiness, ability to eye and swage readily, and a uniform tensile strength. Not only must it be strong enough to withstand a constant 150-lb. tension, but it must do so while vibrating from 27 to 4200 times per sec. The tension should never be more than half the breaking strain or tonal efficiency will be impaired.

Since the bass strings, if made of the usual plain steel wire of normal diameter, would be far too long for practical use, they can be shortened and the excess length replaced with weight. This compensating procedure calls for wound wires because a solid steel wire of the large diameter required would be entirely too stiff for the formation of tonal vibrations and too difficult to handle. Covered wires are made by spinning soft steel or copper wire upon a hard steel core. Experience has built up the required information about the weight of wire to be chosen for a known tension, pitch, and string length, as well as the correct combination of core and covering for that weight.

Tuning pins are of steel about 0.283 in. diameter and 2.5 in. long. Levers in the action between keys and hammers are small pieces of wood pivoted on german silver pins. Springs in the piano action are of brass, and in one make, of phosphor bronze. The supporting structure for the action parts is generally of

While the Piano, as Well as the Harp and Members of the Violin Family, Use Wood for Case and Sounding Boards, Many of the Strings (All in the Piano) Are of Specialized Metal Construction, and the Bill of Material for a Lyon & Healy Harp Contains 38 Items of Metal Stock. (Photo of Steinway Piano by Anton Bruehl)

Piano Plate (of High Strength Gray Iron) Must Resist Without Creep the Combined Torsion and Compression From the Attached Wires, Totalling 50,000 Lb.

wood and cast iron but one firm uses a frame of seamless brass tubing with cast bronze brackets.

Fastenings for the legs and lyre are in dovetail plate form, usually cast or malleable iron. Such things as pedals, casters, hinges, and other miscellaneous hardware are usually made of polished brass.

Much experimenting has been done here and abroad in the use of stainless steel wire, particularly of the 18-8 variety. The problem is not easy, for the tonal and physical qualities of piano wire have been evolved during centuries of use. However, it is quite probable that pianos will have an increasing number of stainless steel wires, tuning pins, hitch pins, and bridge pins. In an effort to reduce the damage by corrosion in humid atmospheres cadmium, tin, or zinc plating has also been tried, but such wires are more difficult to work than unplated steel and are prone to chip, peel, or rupture when twisted and looped. Chromium plate is more promising.

Metals Used in Harps

Problems of construction in the harp are quite similar to those of the piano. It has, however, only 49 strings — there is but one string for each note of the seven octaves and none to correspond to the black keys of the piano. The strings are lengthened for a flat tone and shortened for a sharp tone by means of agraffes or disks with two protruding pins or fingers. These are ranged on the top plate of the harp and are actuated by seven foot pedals connected through the column of the harp to a set of steel levers concealed in the upper frame.

When tuned to pitch, there is a total tension on the harp frame of 1500 lb. Although greater strength would be attained with metal frames, wood is preferable because of its lighter weight and the quality of resonance it imparts to the tone.

The top plate, to which the agraffes and tuning pins are attached, is of a special brass, cold rolled hard to 0.088 in. thick. Agraffes are hard drawn or extruded brass, as are the bridge pins, and the foot pedals. An alloy highly resistant to wear has been developed for this purpose, since wear on the agraffes would produce untrue sharps and flats. Tuning pins are of monel metal, and other rivets, studs, and levers are of steel.

Only 12 of the harp strings are of metal. They are covered wires wound with either fine copper or nickel wire.

Strings

Metal strings for violins, banjos, mandolins, guitars, and ukuleles are of so many different types that the catalogue of one of the leading makers lists over 600 separate items. The violin G string, for instance, is of gut wound with either solid silver or "roll plated" (bi-metal) wire about 0.006 in. diameter. The "plated" wire is made by pushing a base metal rod such as nickel-silver or bronze into a silver tube, welding the two metals together, and drawing this composite rod into fine wire. If gut is to be wound it is held in a lathe and the silver wire wound around it by machine. Other violin strings are plain (not wound) silver plated or copper plated steel. Wound gold wires are sometimes used for the G string, and aluminum wire wound on gut for the D string. Other stringed instruments have similar combinations of strings, as well as some wound on silk or silk-covered steel.

Fret wires for fingerboards of stringed instruments are made of monel metal, nickel-silver, or brass. The latter is used on the smaller and cheaper instruments, such as ukuleles.

CRITICAL POINTS — A WEEK'S DIARY

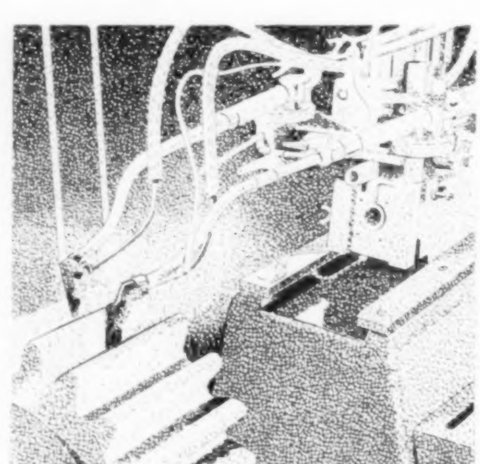
ACROSS the Mississippi by the Eads Bridge (where alloy steel was first used in a structure) into St. Louis' union station. Editorials at the time of its construction spoke of it and its approaches as a triumph of engineering design; many interfering train movements had to be coordinated, and they brought in tow the no less difficult problem of wear on the crossings in the intricate trackwork. I can recall my disappointment, in the summer of the World's Fair, in finding it surrounded by an ugly slum, but happily that is now cleared away and a magnificent mall is being bordered by public buildings and memorials — something enduring to console unborn citizens when the tax bills must eventually be paid.

Should Small Economies Have Credits for Overhead?

Good conversation at lunch with CARL MORKEN of the Carondelet Foundry, E. KUMMING of Century Electric, and BILL ECKENFELS of Vanadium-Alloys Steel Co. (Perhaps there is some obscure connection to the Rome-Berlin axis discernible in the circumstance that this lunch was in a famous Italian restaurant in German-settled San Louie.) We talked of a change which saved 5¢ out-of-pocket cost of a minor machine part, and whether it was proper to load such a cost with the usual overhead (say 100%) and figure that the total saving would really be 10¢ per machine. Some railroading friends had said that no savings from light weight freight cars could be noted until a majority of the old cars had been replaced, but these metallurgists insisted that *any* saving in direct cost should also carry a correct credit for overhead, even though there were no compensating change in the supervisory staff, power bills, and fixed charges. Actually such an accounting practice tends to increase the overhead proportionally on all remaining operations, and it would not take many such additions to readjust the overhead. Otherwise there would be far less urge to keep down the undistributed costs to a correct proportion of the direct costs.

Traveling south from St. Louis to Texas with GUS KINZEL of Union Carbide and Carbon Corp. and JOHN CROWE and GEORGE SLOTTMAN of Air Reduction Co., we talked long and loud about flame hardening. This versatile oxy-acetylene flame, which can weld (and cut) anything from lead to iron, is also good for hardening (and softening), and was, indeed, so used and widely 15 years ago, as a questionnaire to members of the "Steel Treaters" indicated. However, the unique ability to harden the surface of steel and iron pieces, large and small, without heating anything but the required area, was not commercially exploited in America until a few years ago. Now the enthusiasts are trying everything! In its best use, one or more flames of proportionate size heat the surface layers red hot, followed closely by jets of quenching fluid — although in truth much of the heat is drawn inward by the underlying mass of cold metal, and this "self-quenching" action may sometimes be the more important of the two. The degree of surface hardness depends principally on the carbon content of the steel, and its variation inward will resemble that of any sample of steel not hard-

Hardening With Oxy-Acetylene



ened fully to the center. If other conditions are the same the alloy in the steel controls the depth of hardening and also the toughness of the hardened zone.

Numerous other analogies to the more conventional art of heat treatment could be drawn. For example, warpage will be minimized in a symmetrical shape, annealed to relieve internal stresses before machining, and hardened symmetrically about the axis. Flame hardened parts are very tough when properly tempered, even in plain, high carbon steel, as is proved by hardened rail ends and crossing frogs. Ways on lathe beds of high test gray iron or alloy iron, and wearing pads on malleable iron levers, are examples of flame hardening now being done in many plants on materials not ordinarily quenched and tempered.

Considerations such as the above were discussed by Charles E. MacQuigg, Dean of the College of Engineering, Ohio State University, at a special lecture in Houston before the International Acetylene Association. Emphasis in all the meetings at this convention was placed on the practical aspects of welding and cutting as applied to oil field, pipe line and refinery equipment.

Revivified Technical Sessions

Very successful informal meetings advertised as "Round Table Discussions" were held to consider such subjects as welding of oil well casing, testing of welds, safe-ending of boiler tubes, hard facing, welding of alloy steels, welding of non-ferrous metals, fire prevention and safety, reclamation. Another interesting effort to revive the flagging interest in technical sessions took the form of a "panel discussion" on hard surfacing immediately following Dean MacQuigg's lecture, patterned after the Sunday noon programs on national problems broadcast from Chicago University.

In Houston saw Robert Schlumpf, first chairman of the ⊕ Texas Chapter and metallurgical engineer at Hughes Tool Co. This plant and others visited in this vigorous city, reminiscent of roaring 1929, are new, orderly, spread out with lots of elbow room in saw-tooth mill buildings, conforming to land flat as a tabletop. In this semi-tropical climate forging and heat treating shops need have no side walls, and are clean, light and airy — a metallurgist's paradise. From a number of newsworthy operations observed at this huge modern manufactory of oil drilling tools, a coordinated unit for forging tool joints may be reported.

Gargantuan Forgings for Oil Drillers

It consists of an elevated dock for mill-length bars — alloy steel squares, as large as 6x6 in. (they really use alloy steels in this country!) — served from the stockyard by locomotive crane. A roller table feeds these bars, one at a time, endwise past a station where an oxy-acetylene flame automatically cuts off slugs of proper length. The billets slide down a chute to pusher furnaces for heating to forging temperature. These are pyrometrically controlled, fired with natural gas through proportioning valves that keep the gas-air mixture constant at all throttle openings, and at a proper ratio to form a soft and flaky scale. Out of the furnace, one by one they drop down a chute into a small press that pierces one end for a porter bar, and the billet is then swung by hand through the successive dies of an enormous forging machine. Emerges a cylindrical forging with thick walls and tapered ends, and this is dumped on an inclined conveyor to an annealer. It is then ready for the machine shop.

Charles Shapiro, chief metallurgist, Reed Roller Bit Co., wrote such an interesting paper for the Acetylene Association about hard facing materials for oil well drilling tools and bits that it is reproduced in this issue of Metal Progress. Tungsten carbide saved so much money to oil well drillers that, when first introduced under various trade names, they actually paid its weight in gold. Those days are gone forever!

One evening we ate at a restaurant in the Mexican section, and between the enchiladas and the tamales he described the interesting details of making tungsten carbide, now the favorite stuff for hard facing.

Melting & Casting of Tungsten Carbide

Tungsten powder is mixed with a little carbon and melted under a carbon arc and poured into graphite molds. The hardness is very high, — a real diamond substitute — and is an inherent quality of the metal. A small percentage of some added metal like cobalt will increase its toughness, and the method of centrifugal casting may also be used to increase the density.

Cast carbides can be crushed, sized, and, after placing in thin walled carbon or alloy steel tubes, used as welding rods. Small rods, $\frac{1}{8}$ in. diameter containing 30 to 40-mesh particles, can be rapidly flowed onto steel surfaces

such as small teeth on rock bits in layers varying from 0.03 to 0.05 in. thick by either an acetylene torch or a fan-like atomic hydrogen flame. Coarser particles, 20 to 30 mesh, are packed into larger tubes up to ⅜ in. diameter for facing larger cutting edges or wearing areas. In SHAPIRO's opinion, the essential reason for the success of this brittle material under high impact, scraping and grinding action, is the bonding effect of the melting steel tube which "wets" and welds itself to both the ductile base material and the brittle carbide particles. The steel binder, under high impact absorbs the applied blows yet enough of it quickly wears away to expose the resistant carbide to do the real cutting.

Mission Manufacturing Co. is far, far from the center of Houston out Humble Road, but still within the limits of the hopeful city. Here DON GARRISON showed me a thriving and modern shop making pump pistons and piston rods and "slips" (wedges which do the exact opposite from what the word means, that is, prevent a string of drill pipe from slipping back down a deep hole while being withdrawn or reassembled). It's all alloy steel. The pump pistons simply must not fail in service for they force soupy mud called slush at pressures up to 1200 psi. into a drill hole to "lubricate" the tool bits and carry up the cuttings, and a broken rod might demolish pump and surroundings. Material is a fine-grained alloy steel, electric furnace grade, in annealed and ground rods up to 2¾ in. diameter by 5 ft. long. These are gas carburized while hanging in a vertical retort, qenched vertically in a rising column of oil, transferred before getting cold to a draw tank, still vertical, and straightened in a press while cooling from the draw. Ends were previously copper plated to stop off the case so tapers and threads can be cut. Thread contours and surfaces are of greatest importance to avoid damaging stress concentrations. GARRISON said that most trouble in service comes from pitting the polished rod when the slush is salty or brackish; grit carried in these pits chews up the packing rapidly and scores the rod.

Pumping Soupy Mud at High Pressures

With CHARLEY LEWIS of Cook Heat Treating Co. as companion to the huge Port Arthur refinery of the Texas Co., which with another owned by Gulf Refining Co. employs practically all the workers in the city. There was shown about by ENSLO DIXON, who fathered the 5% chromium steel in cracking still service, and his metallurgist HARRY WILTEN. Corrosion and frequent replacement of tubes in condensers and heat interchangers seems to be the principal metallic problem here, and a real problem it is, for there are at least 230,000 such tubes in this one refinery alone. Admiralty brass and red brass are used almost entirely. Their life is various; successive bundles installed in the same condenser shell may last one year, two years, or six months, with no correlation as yet to operating variables (by design or accident), or the nature of the cooling water as affected by rainfall or other climatic conditions. Other types of tubing are continually under test, but their life is also so various under ordinary operating conditions that DIXON is not convinced that any of them is sure to last enough longer to warrant their extra cost.

Brass Condenser Tubes Still Corrode Badly

Returning home via Dallas, arch commercial enemy of Houston, and nearby Fort Worth — both surprisingly large cities in the midst of an almost limitless open plain — to be able to ride on the Rock Island railroad's Rocket. This luxurious diesel-engined train (made horrid by blaring radio) loafs along until it reaches Oklahoma City, but then it really goes to town, getting to Kansas City, 650 miles from the start, at an elapsed time of 11¾ hr. or 55 miles per hr. average. Near Oklahoma City, by the way, is a most extensive and depressing shanty town, libeling what is doubtless a pleasant city, and exhibiting perfectly what *not* to do with corrugated iron. There had been a severe dust storm in this vicinity the day before, and handfuls of red mud were still sticking to the trucks and underframes near water drains and steam drips. The stainless steel exterior of these two-year-old cars is in excellent condition, bright, shiny and unscratched. Owing to careful streamlining there are few projections from a smooth surface; of those there are, however, the leading edges are frosted and pitted as from a sandblast.

Dust Storm Sandblasts Stainless Steel Cars

Engineering Properties of Monel Metal

Data from
International Nickel Co., Inc.

Monel Metal is a solid solution of nickel and copper approximately 67:30, with added elements to control certain properties. Typical compositions are as shown at right:

Product	Ni	Cu	Fe	Mn	Si	C	Al	S
Wrought; Regular	67	30	1.4	1.0	0.1	0.15	...	(Note)
"K" (heat treatable)	66	29	0.9	0.4	0.25	0.15	3.3	0.005
Cast; Regular	67	29	1.5	0.9	1.25	0.3	...	.....
"H" (high strength)	65	29.5	1.5	0.9	3.0	0.1	...	.....
"S" (non-galling)	63	30	2.0	0.9	4.0	0.1	...	.....

(Note) A high sulphur variety called "R" Monel is free machining.

Properties of Monel Metal Castings

Property	Regular	H Monel	S Monel
Tensile strength (1000 psi.)	60 to 80	70 to 90	90 to 115
Yield (1000 psi. for 0.5% extension)	30 to 40	45 to 65	70 to 90
Elongation (% in 2 in.)	40 to 20	20 to 10	3 to 1
Izod impact, ft-lb.	65 to 80	35 to 45	1 to 5
Brinell hardness	125 to 150	170 to 210	280 to 325
Rockwell number	55 to 75-B	......	<32-C

Temperature for slight oxidation ...... 570° F.
Annealing range (standard monel) .... 1400 to 1800° F.
Forging range (standard monel) ...... 1600 to 2150° F.
Pouring range for castings .... 2750 to 2900° F.

Cold-Rolled Sheet and Strip

Temper	Sheet: Shore	Sheet: Rockwell B	Strip: Shore	Strip: Rockwell B	Approx. Tensile Strength
Dead soft	<16	<60	<16	<60	70,000
Soft	......	......	17 to 18	61 to 68	75,000
Soft skin-hard	17 to 20	61 to 73	......	......	......
Skin hard	......	......	19 to 20	69 to 73	77,500
Quarter hard	21 to 24	74 to 82	21 to 24	74 to 82	80,000
Half hard	25 to 30	83 to 89	25 to 30	83 to 89	90,000
Three quarter	31 to 35	90 to 93	31 to 35	90 to 93	100,000
Hard	36 to 40	94 to 97	36 to 40	94 to 97	110,000
Full hard	......	......	>40	>97	120,000

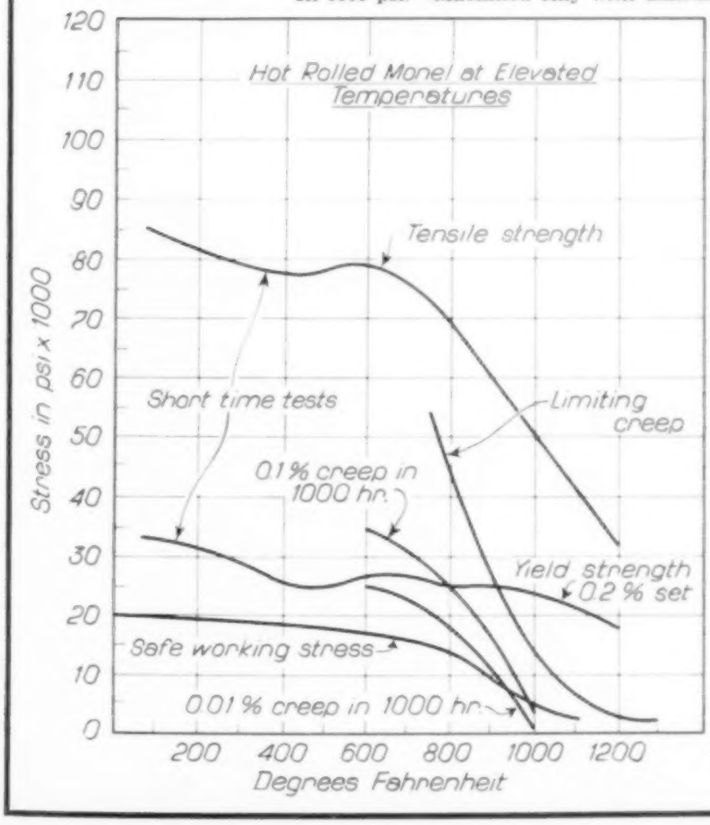
Physical Constants of Wrought Monel

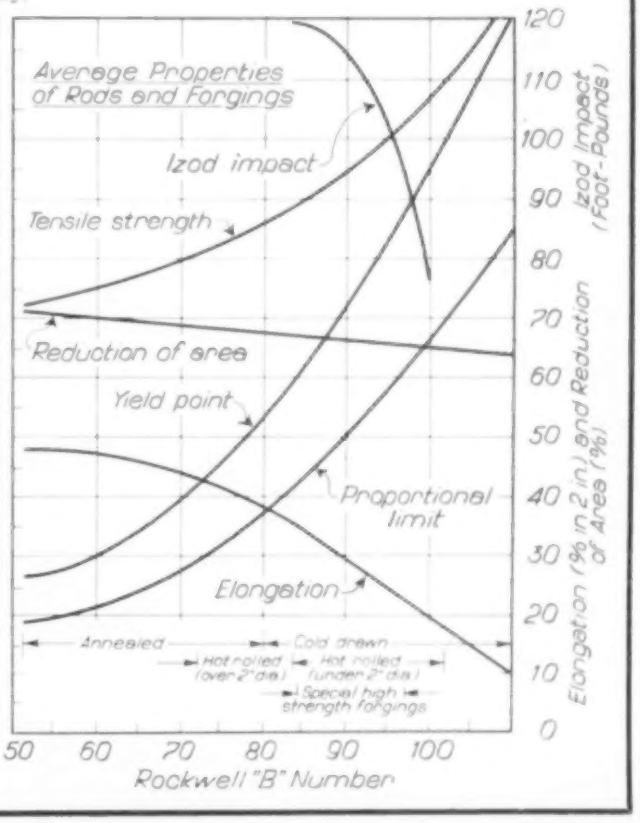
Specific gravity 8.80
Density, lb. per cu.in. 0.318
Melting range
degrees F. .... 2370 to 2460
degrees C. .... 1300 to 1350
Specific heat at (80° to 212° F.)
(27° to 100° C.) 0.127
Heat expansion coefficient
at 80° to 212° F., per °F. 0.0000077
at 25° to 300° C., per °C. 0.000015
Thermal conductivity
at 30° to 212° F., B.t.u./sq.ft./hr./°F./in. 175
at zero to 100° C., cal./sq.cm./sec./°C./cm. 0.06
Electrical resistivity
at 32° F., ohms/circ.mil.ft. 256
at 0° C., microhms/cm.³ 42.5
Temperature coefficient of electrical resistivity
per °F. 0.0011
per °C. 0.0019
Modulus of elasticity
in tension, psi. 26,000,000
in torsion, psi. 9,500,000
Poisson's ratio 0.32

Mechanical Properties of K Monel

Condition	Ultimate*	Yield (0.5% Set)*	Elongation	Reduction	Brinell
Soft, quenched from 1450° F.	<120	<80	>40	>50	<225
Reheated to 1000° F.	120 to 140	80 to 100	>30	>35	225 to 275
Reheated to 1100° F.	140 to 160	100 to 120	>20	>25	275 to 325
Cold worked and reheated to 1100° F.	>160	>120	>15	>20	>325†

*In 1000 psi. †Machined only with difficulty.





CORRESPONDENCE, HOME AND FOREIGN

Application of Steel to Operations at High Temperature

Special letter to METAL PROGRESS
by T. McLEAN JASPER
Technical Consultant, A. O. Smith Corp.

MILWAUKEE, *Wisc.* — In drawing attention (by the Editor of METAL PROGRESS) to White, Clark and Hildorf's paper describing the stress-rupture test in the body of my paper in the February issue, footnote on page 162, you will notice on the same page that H. J. French in 1925 used the same method. French's tests showed also that the longer the time, the lower the rupture strength. When in 1926 the author set up his tests, he thought that the continuously reducing slope was possibly due to progressive oxidation.

The results of the author's testing, it is believed, show this to be a fact because his specimens have all been immersed in a bath of liquid lead during the test, which reduces oxidation to a negligible quantity.

This, it is believed, eliminates the continuous stretch propensity of carbon steel referred to. A specimen which is continuously exposed at high temperatures to oxidation will continuously reduce its cross section and will then continuously extend with a given load.

Regarding the Editor's reference, in the same footnote, to proponents of creep testing, it should be pointed out that 1% stretch in 10,000 and 100,000 hr. means 1% in 1.1 and 11 years respectively. At 900° F. the unprotected ordinary carbon steel will oxidize several per cent of the area of the ½-in. diameter specimens in the 1.1 or 11 years, with the result that one might ask how much of the constant slope value of 1% in the time-stretch curve is creep and how much is elastic stretch due to area reduction. The general answer is somewhat made available when it is realized that various laboratories did produce widely varying results on the same steel, and particularly when testing steels which were exposed to oxidation at high temperatures.

T. McLEAN JASPER

Interpretation of Magnetic Patterns

Special letter to METAL PROGRESS
by ALBERT M. PORTEVIN
Professor, Ecole Centrale des Arts et Manufactures

PARIS, FRANCE — Magnetic patterns, or the configurations formed by the distribution of a magnetic powder in a magnetic field, form classic experiments in elementary physics and have long been used to determine the distribution of a magnetic field and to locate accidental irregularities.

Physical defects such as cracks or holes comprise irregularities in a magnetic metallic mass, and magnetic patterns are frequently used to reveal them. Two methods are principally used: A flat piece is covered by a paper, sprinkled with iron filings, and placed in a magnetic circuit (such as in Roux's tests for welding defects), or the magnetized piece is immersed in oil containing suspended iron filings, or fine powder sprinkled over the surface. The sensitivity of the latter method has been increased by the use of very fine magnetite powders.

Thus it is possible to reveal extremely fine, invisible cracks, very difficult to find by other means; the crack appears clearly in black, traced by the powdery deposit formed along its path. It is thus the magnetic field which traces in powder the pattern of magnetic discontinuities; hence the name "magnetographic testing", a method commercially exploited in America as "magnaflux".

This test is so convenient and definite in

application that the tendency is to generalize and use it as an acceptance method for metallic parts. However, in thus increasing its sensitivity some peculiarities other than discontinuities or cracks are likewise revealed — for instance, non-metallic inclusions, dendritic segregation or macrostructure, segregation of carbides and other metallic constituents.

The appearance of the patterns thus revealed depends not only upon the nature of the magnetic distortion of the metallic mass and the conditions of operation (notably the amount of magnetic powder in the liquid), but also upon

Magnetic Particles Attached to Surface of 18-8 Stainless Steel After It Has Been Smoothed Down to Bottom of a Brinell Impression and a Punch Mark. Magnified three diameters

the orientation of the apparent discontinuity. Interpretation of the patterns observed may therefore be a delicate problem; they spring from widely different origins manifested with variable intensity depending on conditions. Several examples may be given:

The macrostructure of a rolled steel can be revealed if so arranged that the fibers are perpendicular to the field; the lines observed are then the negative of the figures that would be obtained by copper etching of the metal, for the powder collects on the impure portions which are less coppered on etching and which, being less permeable, are magnetically comparable to cracks.

Non-metallic inclusions, which may be indicated, fall under two headings:

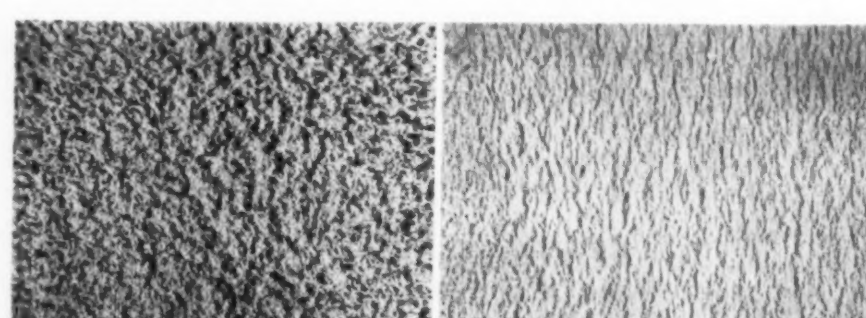
1. If, in a longitudinal section, the distribution of the inclusions coincides with the bands of dendritic segregation (as with sulphides and elongated oxide inclusions surrounded by ferrite), they may be revealed by the magnetic pattern as above described.

2. If, in a longitudinal section, the inclusions are situated outside of the segregated region (as, for example, the stringy silicates), they are revealed by the magnetic powder only when they are sufficiently thick (about 0.1 mm.). Such inclusions cause a local accumulation of powder into a configuration of a length in relation to that of the inclusion — at least to that part of it which is close to the surface and perpendicular to the field.

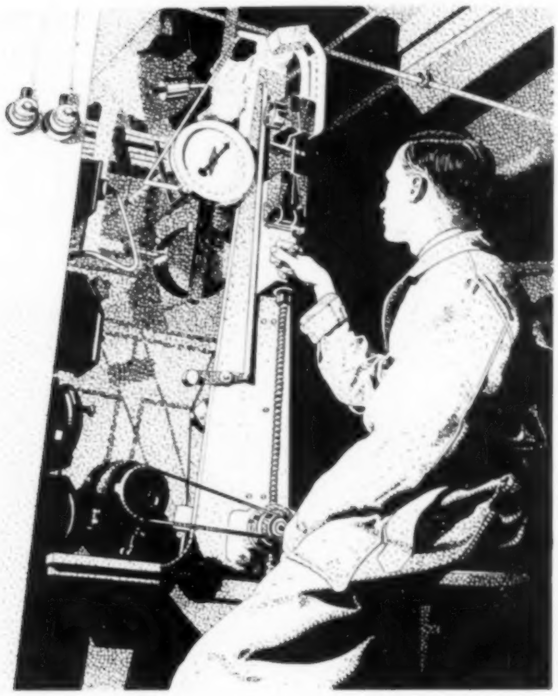
In a transverse section, in which the segregation, fibers and elongated inclusions are perpendicular to the surface of the metal, the influence of such irregularities is notably weakened; the pattern obtained is not very clear. Inclusions emerging at the surface, as well as surface pits, are indicated by a spindle formation with fuzzy ends, perpendicular to the magnetic field.

In short, the result depends upon the length, thickness, the proximity to the surface, and the orientations of the inclusion and the section.

Non-magnetic or only slightly magnetic metallic constituents act in a manner similar to discontinuities; thus, on a longitudinal section of stainless chromium steel containing both ferrite (magnetic) and austenite (non-magnetic), the powder deposits at the borders of the two constituents in a position perpendicular to the magnetic field. Two small views by M. Guitton reproduced herewith were taken of



Photographs, Full Size, of Magnetic Powders Attached to Smooth Surface of Stainless Steel Containing Both Gamma and Delta (Alpha) Phases. At left the direction of forging is perpendicular to the field; at right parallel to it



polished longitudinal sections of austenitic-ferritic steel (18% Cr, 9% Ni, 2.5% Mo, 0.25% Ti); the direction of forging is perpendicular to the field in one and parallel to it in the other; the two appearances are completely different.

Moreover, anything causing deviation in the lines of force or, in other words, anything modifying the permeability, will produce a pattern. Cold work, caused by localized deformation such as scratches, ball indentations or punch marks, is manifested after smoothing the surface to the bottom of the mark. The upper photo gives an example of this in 18-8 austenitic steel.

In short, these patterns indicate the pseudomagnetic lines, or zones of different permeability (due to segregation, cold work, or microconstituents of lesser magnetism), as well as the real magnetic lines or discontinuities in the material (such as flaws, flakes, cracks). The necessity for prudence in interpreting these magnetic patterns is obvious. Physical defects should not always be called their cause and their importance thus overestimated.

This ingenious and precise method falls in the same category as macrography by chemical corrosion (deep etching); so long as it is a question of revealing undeniable and marked defects there is no difficulty, but as soon as an attempt is made to transform the evidence into a quantitative evaluation, consummate competence and experience are required on the part of the observer.

Albert Portevin

Embrittlement of Heat Resisting Steels and Its Cure

Special letter to Metal Progress
by Dr. H. Hougardy
Research Laboratories, Deutsche Edelstahlwerke

KREFELD, *Germany* — Experience has shown that a relationship exists between embrittlement of heat resisting steels and the loss in impact strength after long exposure to operating temperatures. Thus, if a steel loses in impact value after long heating at say 450° C. (850° F.), either under load or unloaded, it must be inferred that this steel will develop a brittle fracture without deformation in practical operation, while, inversely, material that lost no impact strength will retain most of its original ductility in service. This relationship has enabled us to investigate the tendency toward brittle fracture by determinations of the notched bar impact strength.

As the result of these studies we believe that — outside of metallurgical conditions — the composition of the steel is the most important factor, and that the alloying element nickel may well be replaced by molybdenum, which not only raises the endurance limit but also lessens the tendency toward brittleness at operating temperatures and, in combination with chromium, even acts to inhibit brittleness.

The cracks caused by fracture without deformation are intercrystalline. Thus the cause of the embrittlement lies in an alteration of the metal at the grain boundaries. Pronounced thickening of the grain boundaries can be observed in a micro-section. The true nature of this change has not yet been explained, but the brittleness can be removed by a heat treatment, as shown in the following example:

A threaded bolt of chromium-nickel-molybdenum steel (0.15% C, 1% Cr, 1.5% Ni, 0.9% Mo) has, in the as-received condition, an impact value of about 20 m-kg. per sq.cm. After 4000

Recovery of Embrittled Cr-Ni-Mo Steel After Annealing

Condition	Impact Value, m-kg./cm²	Tensile Strength, psi.
Embrittled in operation	3.4	125,000
Annealed 1 hr. at 935° F.	8.0	128,000
975	9.0	128,000
1000	9.5	127,000
1045	10.5	126,000
1085	17.0	125,000
1110	18.0	123,000

hr. of service at 450 to 480° C. (900° F.) this bolt broke and samples cut from it showed an impact value of only 3.4 m-kg. per sq.cm. Upon heating this bolt to 610° C. (1130° F.) for 1 hr., the impact value increased considerably, and after a 10-hr. heating period it reached a value of 22 m-kg. per sq.cm., although the tensile strength fell from 120,000 to 100,000 psi. The influence of heating 1 hr. at increasing temperatures below the transformation point on the impact strength of an embrittled Cr-Ni-Mo steel is shown in the first table, page 379.

A means is therefore provided for checking the tendency toward embrittlement in operation, without running the risk of premature fracture, thus: Anneal the bolt after a certain period of service at a temperature of about 1100° F. for 1 hr.

The development of heat resisting and creep resisting steels in Germany has now led to completely nickel-free alloys — a fortunate circumstance, for all our nickel must be imported. Composition and properties of the steels in common use are summarized below:

Creep Resistance of German Alloy Steels

Composition				Creep Strength, Psi.				
C	Cr	Ni	Mo	400° C. (750° F.)	450° C. (850° F.)	500° C. (935° F.)	550° C. (1025° F.)	600° C. (1110° F.)
0.25	1.1	....	0.30	64,000	50,000	28,000	11,500	4,300
0.12	0.90	....	0.70	43,000	38,000	31,000	21,000	8,500
0.15	0.80	1.50	1.0	71,000	57,000	35,000	25,000	11,500
0.25	1.40	....	1.20	71,000	57,000	40,000	28,000	14,000

The formerly prevalent Cr-Ni-Mo steel is included in the third line in order to show that the Cr-Mo steel listed in the last line possesses as high creep strength as the Cr-Ni-Mo.

The following statements may be made concerning the causes of embrittlement:

1. The cause of fracture without deformation also causes general brittleness of the steel.

2. This brittleness is characterized by marked alteration at the grain boundaries.

3. Such "hot brittleness" is comparable to temper brittleness; that is, a steel which is temper brittle will also tend to brittleness on prolonged exposure to high temperature.

4. Hot brittleness can be practically eliminated by the use of a nickel-free steel containing mainly chromium and molybdenum in percentages so specified that any structural change in the grain boundaries is suppressed as far as possible.

H. Hougardy

Metallographic Terminology

Special letter to Metal Progress
by F. Poboril
Research Laboratories of the Skoda Works

PILZEN, *Czechoslovakia* — Recently a series of communications was published in Metal Progress discussing the terminology of various microstructures in steel. The opinions of the authors widely differ.

I fully agree with the closure by the Editor, appended to the paper by E. G. Mahin in September 1938, namely, that metallographic terminology cannot be standardized before an agreement in the interpretation of the experimental facts. Therefore I am returning to this subject (which I have already discussed with V. Koselev in this journal in March 1935, when we expressed definite suggestions for solving this problem of nomenclature for hypo-eutectoid carbon steels).

I shall answer first the questions put by the Editor, because they furnish a very suitable formulation of the main points of the metallographer's problem:

1. "Is it possible for hypo-eutectoid austenite to transform between Ar_1 and Ar' into any other structure than ferrite plus a lamellar mixture of ferrite and carbide?"

According to the present state of our knowledge the answer must be negative. Point Ar' is defined as the depressed temperature at which austenite still transforms into a lamellar mixture of ferrite and carbide. This temperature depends on the cooling rate for a given steel.

2. "Is the acicular structure resulting from transformation at some constant temperature between Ar' and Ar'' in any way different from martensite?"

X-ray investigations teach us that it *is* different. Martensite is a tetragonal phase, the lattice constants of which vary according to its content in carbon; it has, therefore, the properties of a solid solution. On the other hand, the acicular component appearing between Ar' and Ar'' has a cubic structure, differing from that of the alpha phase by a somewhat larger parameter and by diffuse lines in the spectrogram.

3. "Can martensite be converted on temper-

ing into anything but a dispersion of carbide particles in a matrix of ferrite?"

As long as the term "carbide" means simply a phase rich in carbon, and the term "ferrite" means a cubic alpha phase with a very low carbon content, the answer will be negative.

The answers to the principal questions quoted above constitute a logical basis for metallographic terminology of steel such as we have suggested in our communication in March 1935. The structures differing in their genesis and appearance have to be differentiated by special terms.

According to genesis the structures should be divided into two main groups:

I. Structures resulting from a direct transformation of the gamma phase.

II. Structures resulting from a rearrangement of other phases or structures.

Both of these groups may be further divided into two sub-groups according to the appearance of the resulting structures:

I_1. Austenite transforming at Ar_1 into a lamellar structure called "pearlite", or at the depressed temperature Ar' into a very fine lamellar structure called "troostite".

I_2. Austenite transforming between Ar' and Ar'' into an acicular structure known to be "cubic martensite", or at Ar'' into an acicular structure known to be "tetragonal martensite".

II_1. Disperse structures containing either cubic or tetragonal martensite (that is, the acicular constituents) transform on tempering to a disperse structure known as "sorbite" of varying fineness and homogeneity.

II_{2a}. Disperse structures containing either pearlite or troostite (that is, the lamellar constituents) change during special heat treatment — usually an annealing below Ac_1 — into a disperse structure dubbed "globulite" by Prof. Glazunov of the Pribram School of Mines, a spheroidized carbide of varying fineness and degree of spheroidization.

II_{2b}. Disperse structures containing sorbite (homogeneous or heterogeneous) change during a reheating to temperatures below Ac_1 to a disperse structure consisting of spheroidized carbide of varying fineness in ferrite.

In the above it is not stated that the change from tetragonal martensite to homogeneous sorbite goes through the intermediate stage of cubic martensite, because the latter does not appear as a separate structure, although it can be detected by X-rays.

F. Pobořil

Post Graduate Education in Industrial Metallurgy

Special letter to Metal Progress
by Federico Giolitti
Sometime Professor, Royal Polytechnic College, Turin

TURIN, *Italy* — The problem of giving a really practical training to young metallurgical engineers has received a great deal of attention in Italy during the last few years, especially from industrial concerns directly interested in its solution. The peculiar characteristics of this problem — in addition to those connected with the general problem of practical industrial training — could be divided in two classes, the first including those peculiar to the metallurgical industries in general and the second, those depending on the special conditions under which the metallurgical industry has developed in the confines of Italy.

It would be superfluous to dilate on the problems of the first group, well known to educators everywhere.

As to the second, it may be remarked that the very recent development of the Italian metallurgical industry, in point of years, has enabled us to take advantage of the experience gained in other countries, and to avoid many fundamental errors. For instance, in Italy no attempt has ever been made by high technical schools of college, university or post graduate grade to give a so-called "semi-industrial" training in "practical" metallurgy, as previous experiences in other European countries have repeatedly and clearly proved that a "practical" training on a "semi-industrial" scale was not industrial at all, and still less practical. The school cannot imitate the factory.

The poor results obtained with such semi-industrial schools abroad seemed to prove that the direct object of advanced academic teaching should be limited to solid and complete scientific instruction, based on serious laboratory training, thus giving the student a full and exact knowledge of the laws governing the processes forming the basis of a given industry. In other words, university training should supply the student with all the elements for the efficient study of industrial processes (and the undergraduate and graduate training should go no further) but this latter study should take place subsequently, on a really industrial scale. It should be evident that this last stage of technical training could only be performed in schools and

laboratories directly connected with industrial plants. For this, direct cooperation of private industry was necessary.

The first important example of this cooperation in the field of metallurgical training was given by one of the greatest Italian industrialists, the late Ernesto Breda.

The Breda Company — founded by him at the end of the last century — is a very large and complex engineering and metallurgical enterprise, including steel works, rolling mills, forges, foundries, shipyards and engineering works. Its products include practically all the engineering industries, including metallic products of every description, mining machinery, all kind of ships, motor trucks, airplanes and engines, all railroad material, locomotives (both steam and electric), diesel engines, large electric machinery, arms (especially machine guns) and ammunition.

In order to centralize the technical control of all these works, large laboratories had to be built immediately after the War. When planning them, Ernesto Breda had in view not only the problems of control and research for his own firm, but also the foundation of a new type of technical school based on the principles above mentioned.

By agreement with the Ministry of Public Instruction, a number of scholarships were founded, and are regularly open to young men who have obtained a doctor's degree in chemistry, physics or engineering. These scholarships are awarded after public examination of all applicants. During one or more years the students do technical control and research work in the Breda laboratories, being in constant and close touch with the factories. They are then given junior executive places, either somewhere in the works of the Breda Company, or in other Italian firms.

Though it is probable that the best students now go to the Breda works, still the fact remains that the company does not hesitate to give to other companies (at least indirectly — sometimes to their competitors) the advantage of some of their technical experience.

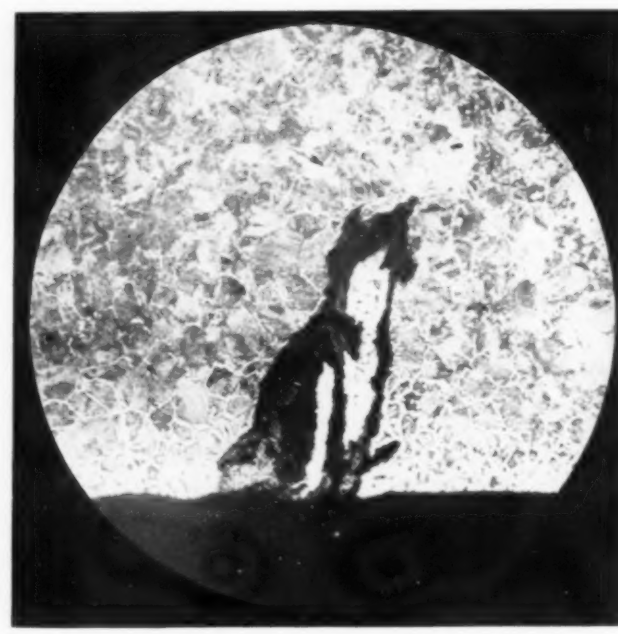
The results obtained during nearly a score of years with this training, performed in really industrial surroundings, have been excellent in every respect, and many other metallurgical companies, including "Ilva", the largest Italian metallurgical concern, are following practically on the same lines.

FEDERICO GIOLITTI

Ghosts

CHICAGO, *Ill.* — As an addition to the Editor's collection of leprechaunes indicating some connection between metals and, perhaps, spiritualism, I am sending a ghost found some time ago. Some call it a lap in the base of a railroad rail, but it seems to me quite plainly the wraith of a cat — one of the kind that loved to sit on a fence and give a midnight serenade.

RICHARD K. AKIN



Large Amounts of Radium
more effective in radiography of steel

Special letter to METAL PROGRESS
by HERBERT R. ISENBURGER
President, St. John X-Ray Service, Inc.

LONG ISLAND CITY, *N. Y.* — Some experience recently gained in radiographing very thick steel pieces with gamma rays from radium indicates that there is a considerable advantage in using as large an amount of radioactive material as possible. For example, for a piece of cast steel $9\frac{1}{2}$ in. thick (thought to be a record) we used 500 mg. at 15 in. focus-to-film distance for a period of five days, which is in accordance with the charts given in our book on Industrial Radiography, but less than one-third of the time recommended by the U. S. Navy charts. The actual area covered satisfactorily was about 10 in. in diameter or $\frac{2}{3}$ the focal-film distance. This limitation is due to the increased thickness

to be penetrated by the rays toward the edges.

A penetrameter $\frac{3}{16}$ in. thick was placed on the side facing the radium source and another one of the same thickness was attached to the film holder. Only the penetrameter nearest the film showed on the gammagraph.

The regular photographic procedure recommended for this type of work was followed: Two duPont safety X-ray films between three lead foils 0.06 in. thick, developed with potassium iodide at slightly over 70° F. for 10 min. (a 10% increase over the regular developing temperature).

As remarked above, we learned that a larger amount of radium is much more effective than has been taken for granted by workers who derived their beliefs after using small amounts of radium only. This was particularly noticeable when we checked the protective efficiency of the container. While this very same container may be perfectly safe for transporting 100 mg. of radium, it is absolutely unsafe for the use of 500 mg. We have such evidence in our files and again emphasize the necessity of proper protective devices, as indicated in METAL PROGRESS of June 1935, page 60, and in *Metals & Alloys* for April 1935.

HERBERT R. ISENBURGER

Determination of Lead
in carbon and alloy steels

EDITOR'S NOTE — In view of the sudden interest in lead-bearing steels for their machining qualities, the following communications concerning analytical methods have enough "spot news" value to warrant an exception to METAL PROGRESS' rule of avoiding discussion of analytical technique.

Letter from DR. LUNDELL:

WASHINGTON, *D. C.* — Since the commercial production of lead-bearing steel is a rather recent development, accurate methods for the rapid determination of this element in steel are in a stage of development. We at the National Bureau of Standards have analyzed a few lead-bearing carbon steels (containing in the neighborhood of 0.25% lead) by making a separation of the lead as sulphide, dissolving the sulphide, and depositing the lead electrolytically as PbO_2. A copy of this procedure follows.

Committee E-3 of the American Society for Testing Materials has appointed a sub-committee to study methods for the determination of lead in steel and draw up a recommended method, or methods. Arba Thomas, chief of the Chemical Laboratories of the American Rolling Mill Co. is chairman of this sub-committee, and it is hoped to have a report by June 1939. In connection with the work of this committee it is likely that the National Bureau of Standards will undertake the preparation of a standard analyzed sample of lead-bearing steel.

G. E. F. LUNDELL

Determination by Sulphide Electrolysis

Dissolve 5 g. of the sample in a mixture of 17.5 ml. HCl (sp.gr. 1.19) and 100 ml. of water. When solution is complete dilute to 250 ml. and heat to boiling. Pass in H_2S while the solution cools to room temperature and let the precipitate settle well before filtering. Filter on a tight paper and wash the beaker and precipitate with 1% HCl solution saturated with H_2S. Return the paper and precipitate to the beaker and wash most of the precipitate loose from the paper with a jet of water from a wash bottle. Add 40 ml. diluted HNO_3 (1:1) and boil gently until the sulphides are decomposed. Filter the solution through a loose paper, into a 250-ml. beaker, wash thoroughly with 2% HNO_3 solution, dilute the filtrate to 200 ml. and electrolyze, using a weighed platinum gauze anode and a current of 0.2 ampere for about 4 hr. Without interrupting the current, wash the anode with cold water as it is withdrawn from the solution. Dip the anode into a beaker of water and then rinse with water, dry for a few minutes at 110° C., cool, and weigh as PbO_2. The weight of the deposited PbO_2 multiplied by 17.32 gives the per cent of lead in the sample.

Letter from CHARLES MORRIS JOHNSON:

PITTSBURGH, *Pa.* — The writer has had quite an extensive search made in the Park Works Laboratory of Crucible Steel Co. of America for a method to avoid low determinations of lead in plain and alloy steels. This is rather a delicate matter, and our findings are given below.

First a note about a useful qualitative test may be in order; this will detect 0.04% lead (2 mg. in a 5-g. sample). When small amounts are suspected a blank should be carried along at the same time on a similar steel known to be free of lead.

Dissolve 5 g. of sample in a 600-ml. beaker by heating with 150 ml. H_2SO_4 (1:3). Oxidize with 1 to 2 ml. 30% H_2O_2, and boil off excess H_2O_2. Evaporate to SO_3 fumes and cool. Add 150 ml. H_2O and heat until all but lead sulphate is dissolved. Cool and add 50 ml. absolute ethyl alcohol. The lead will

show as a heavy white precipitate on the bottom of the beaker. Tungstic acid will interfere if present in sufficient quantity to conceal the $PbSO_4$; also zirconium, columbium and tantalum.

As to our quantitative method, it has been tested many times by adding known amounts of lead to steels that do not contain lead, and has gotten accurate recoveries. The precision of the method for technical purposes is as good as any method now in use for other elements; such as manganese for example.

If the proper conditions are not met, such as degree of acidity, some of the lead remains behind in the solution and is lost. Furthermore, in the usual gravimetric determination of lead as sulphate, the latter is easily reduced in part to metal and the operator will be weighing part metallic lead and part lead sulphate. If lead is precipitated from solution of iron, molybdenum, and other alloying elements with H_2S, the free acid must be extremely slight — just barely enough of it to keep iron from precipitating as sulphide — or low results will be gotten.

Charles Morris Johnson

Determination as Lead Sulphate

Dissolve 5 g. of sample in about 50 ml. HCl (1:1) in 400-ml. beaker. Keep at digesting heat until the iron seems to be decomposed, and maintain the acid at 50 ml. Cool and oxidize the solution by adding a slight excess of 30% H_2O_2 (about 20 drops). Cool. Add 100 ml. H_2O and filter out any insolubles through 11-cm., double rapid, low ash papers. Wash same thoroughly free of iron with H_2O acidulated with a few drops of 1:1 HCl, catching the filtrate and washings in a 500-ml. cone flask. Ignite insolubles in a weighed platinum crucible and remove Si as usual with HF and a slight excess of H_2SO_4 (1:7). Hold this for possible examination for lead. To the filtrate and washings from the siliceous insolubles add filtered NH_4OH (1:1) until there remains a slight red cloud of iron hydroxide that does not dissolve on thorough stirring.

Dilute to 350 ml. with H_2O. Heat to boiling. Remove from heater. Add 4 ml. ammonium acetate. Mix well. Pay no attention to any slight red precipitate but pass H_2S through the hot solution at once and for one hour at a fairly rapid speed. Filter the precipitated sulphides of lead, copper, molybdenum and tin onto double rapid, low ash papers. Wash with 500 ml. H_2O plus 5 drops of HCl saturated with H_2S — 50 washings. Burn off the papers from the sulphides at the *lowest* visible red heat.

These papers are burned off in porcelain crucibles. Brush the main char-free residue into 150-ml. beakers. Boil 5 ml. conc. HCl in the porcelain crucible to remove completely any residue that adheres to the crucible. Add this HCl to the beakers and add 5 ml. HNO_3 (1.20 sp.gr.) and digest until any lead buttons are dissolved. Then add 12 ml. lead sulphuric acid prepared as noted below. Take to SO_3 fumes. Redissolve in H_2O and take to fumes again. Cool. Add 40 ml. H_2O and bring to boil. Remove from heater and add 25 ml. absolute ethyl alcohol. Stir and cool; settle over night if possible. Filter in Jena glass crucible C fine grain, 1-b-G-4 crucible, prepared as follows:

The clean crucible is first brought above 100° C. on a hot plate, then placed in a muffle at the lowest visible red heat. It is brought to this temperature, held for about 5 min., removed and placed again on the hot plate and from there into a desiccator. It is weighed when at room temperature.

The lead sulphate is filtered into the crucible; washed with 30 ml. 1:3 H_2SO_4 + 500 ml. H_2O + 25 ml. absolute alcohol, with slight suction; dried on hot plate and then ignited as before; cooled and weighed as $PbSO_4$. Tungstic acid (also zirconium, columbium and tantalum) will interfere if present in sufficient quantity to conceal the $PbSO_4$. Impure lead sulphate can be readily dissolved by warming it with ammonium acetate solution [270 g. $NH_4(C_2H_3O_2)$ crystals dissolved in 250 ml. H_2O + 10 ml. 1:1 NH_4OH, filtered] which leaves many impurities in insoluble form. These can be filtered out, washed and the lead reprecipitated in the filtrates. Modify the method for high chromium steels as in the last paragraph.

The weight found in $PbSO_4$, in parts of a gram, times 68.32 and divided by the weight taken for the analysis gives the percentage of lead in the sample. By this procedure 2 mg. of lead are discernible in a 5-g. sample, equivalent to 0.04% Pb. To detect such a small amount a qualitative blank of a similar steel containing no lead should be carried along at the same time.

Dilute lead sulphuric acid is formed as follows: Weigh 100 mg. lead into 800-ml. beaker. Dissolve by boiling in 250 ml. conc. H_2SO_4. Cool to room temperature. Slowly add 600 ml. H_2O. Stir; decant; filter as needed. Use great care in handling boiling conc. H_2SO_4 as it is very dangerous.

If chromium is of the order of 16% the foregoing practice should be modified after the place where the sulphides have been ignited to remove the paper char. Then brush the entire ash into a small beaker and digest it first with 20 ml. of 1.20 sp.gr. HNO_3. Then add 50 ml. of conc. HCl and continue the digestion until there are no heavy insolubles (the latter, if any, float around and remain in suspension for a time when the contents of the beaker are stirred). These floating insolubles are dark. Filter these out; wash; evaporate filtrates and washings with the leaded sulphuric acid and finish as already described. These insolubles are mainly chromium oxide. We have not detected any lead in them as yet.

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THREAD HOBS

(Continued from page 368)

Thread hobs with spiral flutes are now used more generally than those with annular grooves; they have many advantages such as a smoother cutting action, a much higher speed of operation with a deeper cut, factors which naturally result in a greater accuracy.

Sometimes for greater accuracy or to insure concentricity it is desired to have the thread hob "top" the work — in other words, cut the outside diameter as well as the thread form. Tools for this service are called "topping hobs". The user should make known such requirements, for otherwise hobs are ground with a clearance at the root of the thread, the hob manufacturer presuming that the outside diameter of the work is finished as an independent operation.

Generally speaking, the foregoing observations apply to multiple thread hobs for producing the National form of thread or other V-type thread forms, but hobs are also made to produce the Acme form of thread and various special forms. For the latter the hob designer is faced with the problem of redesigning the thread form in such a manner as to compensate for the error produced by the sweep of the milling cutter as it passes through the area of contact with the work and advances in the path of the helix angle of the thread. This in shop parlance is known as "flank interference". To compensate for flank interference the thread form of the hob is modified by an amount which is best found by layout rather than by any prescribed formula.

Relieving the threads in a ground-thread hob is a very important operation. Insufficient relief will cause the heel of the land to drag, resulting sometimes in torn teeth and making it necessary to regrind the whole tooth form to salvage the tool.

The type of steel used in the manufacture of thread hobs is also important. From much experimenting it would seem that 18-4-1 high speed steel gives good results on most work. Sometimes a cobalt high speed steel has proved more efficient. Good furnace conditions are necessary when hardening tools made of cobalt high speed owing to its tendency to form a soft skin when improperly hardened. For maximum efficiency slightly higher temperatures are used than when hardening regular high speed steel.

It is not the intention to discuss such subjects as speeds and feeds. It will be sufficient to say that ground-thread hobs properly made of high speed steel can now be operated at rates far greater than were thought possible some years ago.

PERSONALS

Arne Hedstrom, formerly with Uddeholm Co. of America, Inc., is now on sales-service for the Vanadium-Alloys Steel Co.

Appointed vice-president in charge of operations, American Steel & Wire Co.: **Harvey B. Jordan**, assistant vice-president since 1937.

David Levinger has been appointed as assistant to **C. L. Rice**, vice-president and works manager, Hawthorne plant, Western Electric Co., and will succeed Mr. Rice when he retires at the end of 1939.

John J. Crowe, research engineer for Air Reduction Sales Co., has been awarded the James Turner Morehead Medal of the International Acetylene Association at the Houston meeting.

H. L. Anthony is leaving the Midvale Co. to take a position with Mellon Institute of Industrial Research, Pittsburgh.

R. P. Swartz, formerly of Baltimore, has been made plant manager for Crown Can Co., Philadelphia.

Fred Grotts, formerly vice-president and works manager, Chicago Steel Foundry Co., has been elected president and a director, Fort Pitt Steel Casting Co., McKeesport, Pa.

Clarence E. Sims, metallurgical supervisor, Battelle Memorial Institute, Columbus, Ohio, is visiting in England for the purpose of studying developments in the iron and steel industry.

Promoted: **Lester A. Lanning**, chief metallurgist, New Departure Division, General Motors Corp., Bristol, Conn., from superintendent of the heat treating division to assistant plant manager. **John C. Kielman**, formerly assistant superintendent, has been promoted to superintendent of heat treating.

Appointed chairman, Ferrous Metals Committee, Industrial Gas Section, American Gas Association: **Clayton S. Cronkright**, Public Service Electric and Gas Co. of New Jersey.

Promoted by United Shoe Machinery Corp., Beverly, Mass.: **E. L. Bartholomew**, past chairman, Boston Chapter, to chief engineer; **J. V. Baxter**, member of Executive Committee, Boston Chapter, to superintendent of inspection.

Honored for his services to the metallurgy of the region: **Bradley Stoughton**, national treasurer, dean, and head of metallurgical engineering, Lehigh University, Bethlehem, Pa., at a dinner of the Lehigh Valley Chapter.

Roger Waindle, formerly with the Hoskins Mfg. Co., is now sales manager for the Fahralloy Co., Harvey, Ill.

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PERSONALS

George K. Manning has accepted a position as metallurgist, Republic Steel Corp., South Chicago plant.

James F. Konopasek has been made assistant fuel and combustion engineer, Rolling Mill Division, South Works, Carnegie-Illinois Steel Corp.

George I. Calvert, formerly metallurgist for Texasteel Mfg. Co., Ft. Worth, is now assistant research engineer, Reed Roller Bit Co., Houston, Texas.

Walter P. Wallace, metallurgical department, Columbia Steel Co., will be in San Francisco for about five months in charge of the research exhibit of United States Steel Corp. at the Golden Gate International Exposition.

Thomas L. Counihan has resigned as metallurgist for the Fitchburg factories of Simonds Saw & Steel Co., to become assistant chief metallurgist, Hyatt Roller Bearing Division, General Motors Corp., Harrison, N. J.

Coleman S. Williams, formerly metallurgist for the Intertype Corp. of Brooklyn, is now engineering assistant to the general manager, Winchester Repeating Arms Co., New Haven, Conn.

R. B. Sosman, United States Steel Corp. Research Laboratories, has accepted the chairmanship of the Metals Industries Committee for the forthcoming High Temperature Symposium of the Amercian Institute of Physics.

Arthur Nordquist of Flinn & Dreffein Co., Chicago, has sailed to India to superintend construction of six pack and pair furnaces for the new sheet mill of the Steel Corp. of Bengal.

Charles T. Williamsen, formerly representative for the Torrington Co. in Dayton, Ohio, is now associated with the metallurgical department of the Hyatt Roller Bearing Division of General Motors Corp., Harrison, N. J.

James A. McKinley is now metallurgical contact representative in the Cleveland sales office of Carnegie-Illinois Steel Corp.

Transferred by National Malleable & Steel Castings Co.: **Harold H. Johnson**, to Sharon plant as plant metallurgist.

William T. Robins is now in the metallurgical department, Ensley Works, Tennessee Coal and Iron, Birmingham, Ala.

Granted leave of absence from Westinghouse Electric & Mfg. Co.: **Edward J. McBride**, to study at Harvard University on the Lamme Scholarship for 1938-39.

Transferred: **Muir L. Frey**, service metallurgist, Republic Steel Corp., from Buffalo district to Detroit office.

BORON CAST IRONS

By P. G. Bastien and L. Guillet, Jr.

Abstract from Carnegie Scholarship Memoirs, 1938.

SINCE VERY LITTLE has been published concerning the effect of boron in cast iron, other than the fact that a small amount will prevent graphitization, the present authors thought it desirable to take up the subject again, and studied a series of nine cast irons which they made in small electric furnaces. Boron was introduced by a 10% ferroboron. Much boron was lost when melting in an arc furnace under a slag deoxidized with ground wood charcoal; recoveries were better in a small high frequency furnace using a slag of molten silica and glass. Boron in our alloys ranged from 0 to 1%; other elements were reasonably constant and about: Total carbon 3.5%, silicon 1.5%, manganese 0.45%, sulphur 0.01%, phosphorus 0.05%.

In the first series of castings so made that the boron-free iron had a chill ⅛ in. deep, boron had little effect until it exceeded 0.1%, but 0.2% boron produced a 1-in. chill, and the test casting was entirely white at 0.4% boron. Microscopic examination of these samples showed no unusual features, as might be expected from Tammann's provisional structural diagram. The analyses lay within the region where the ferrite contained some boron in solid solution and the carbide contained some boride (Fe_2B) in solid solution. The complex carbide etched like ordinary cementite in boiling sodium picrate.

Boron does have an observable effect on the free graphite: the amount determined chemically as graphitic carbon steadily decreases with increasing boron and under the microscope the number of particles and the length and thickness of the filaments decrease. Again, when the percentage of boron increases, the graphite filaments tend to accumulate in colonies, this distribution being particularly marked in the cast iron containing 0.180% of boron, which has reduced the graphitic carbon from an original 2.7% to 1.25%.

Graphitization of these white irons was studied, and some interesting data secured concerning the Curie point or "A_0 anomaly" of cementite at about 400° F. Increasing amounts of boron raised this temperature; at 0.3% B it is 450° F., at 0.65% B it is 500 to 575° F., and at 1% B it is 575 to 625° F. The rate of graphitization may be inferred by the changes in the amplitude of the A_0 range during repeated heatings and coolings; if boron is less than 0.2% these changes are what would normally be expected in a boron-free iron. With higher boron, however, the A_0 changes are stabilized after the first heating cycle, indicating a constant amount of cementite — that is to say, *(Cont. on page 400)*

HELD OVER
The KIT-KAT GIRLS
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BORON CAST IRONS

(Cont. from p. 396) higher boron has a marked restraint on the decomposition of cementite.

Hardness changes after annealing cycles agreed with these conclusions. Graphitization of the 0.3% B was practically finished with one cycle, the hardness having dropped from 635 to 205; after four cycles the 0.65% boron iron had dropped from 635 to 284 Brinell; the iron with 1% B softened only to 436 Brinell, with practically no action on further reheatings after the second. In the range of boron contents studied by the authors, this element does not appear to affect the temperature at which growth accompanied by graphitization occurs.

Hardness induced by boron was studied in the first series of castings described at the outset. Brinell hardness of the chill increased directly with boron content from 520 for the boron-free iron to 625 for the 0.4% boron iron. Center hardness also increased proportionately, 190 for the gray iron, boron free, up to 502 for the all-white iron containing 0.4% boron. Shear strength increased from about 30,000 psi. for boron free to 45,000 psi. for 0.2% boron; static transverse strength from 140,000 to 200,000 for the same limits; Young's modulus from 12,500,000 to 22,000,000 psi. Deflection at rupture held rather constant to 0.1% boron, but then dropped sharply.

Chemical analysis is difficult and the method finally adopted was suggested by the Creusot laboratory. The sample is dissolved in dilute H_2SO_4, the solution neutralized and a mixture of alcohol and glycerine added. This forms a glycero-boric complex which is titrated with 0.1 N caustic soda with a phthalein indicator. The caustic soda solution is standardized against a solution of borax treated in the same way.

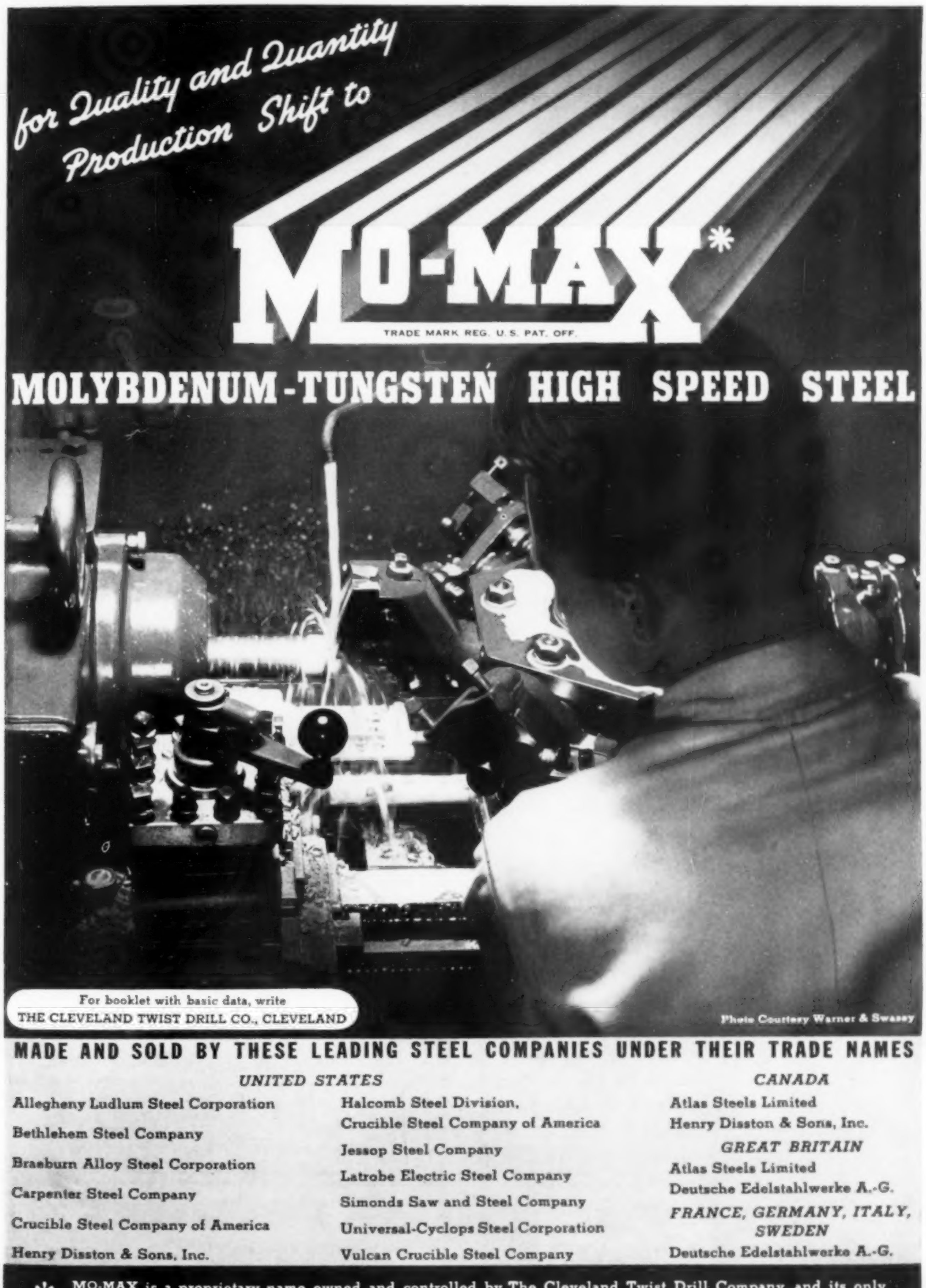
The conclusions emerging from these tests on boron cast irons may be briefly summarized:

1. As had previously been indicated, boron inhibits the graphitization of cast irons when they are solidifying, and acts as an energetic whitener of the structure.

2. Boron similarly opposes graphitization during annealing, by slowing down the speed of decomposition of the cementite, but it does not appear to affect the temperature of incipient graphitization, at least in the range of boron contents studied by the authors.

3. Boron uniformly and rapidly raises the A_0 temperature — a result which confirms the existence of the complex cementite (Fe_3C-Fe_2B).

4. A small amount of boron raises the mechanical properties (hardness, transverse strength and shear strength) of gray cast irons, but reduces their capacity for deformation (deflection).



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1

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2

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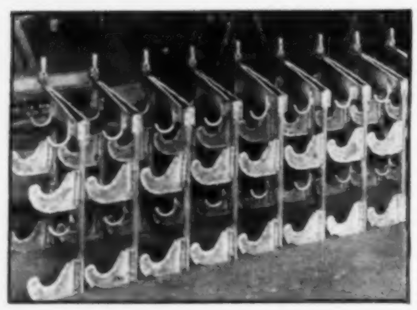

3

The cast iron arm of a circular shear was cracked and repaired, saving $30. How would you weld it? If the weld had to be machined, how would you weld it?

4

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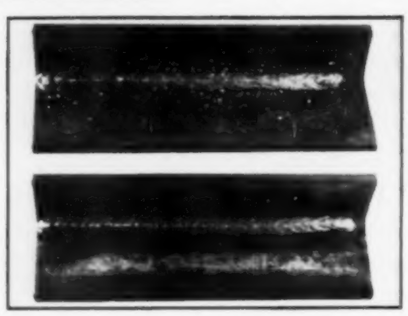

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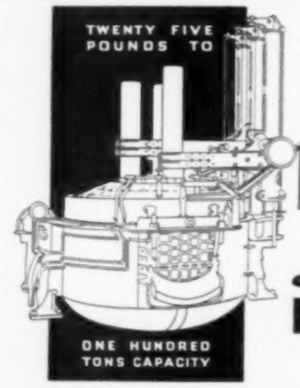

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AGE HARDENING

(Continued from page 354)

heat treatable aluminum alloys, which are daily increasing in quantity and variety. In aircraft fuselage construction alloys of the duralumin family still hold supreme; other alloys are being developed which, in the "as-cast and heat treated" state, possess superior properties when aged above room temperature for considerable periods.

The production of new alloys, the perfection of their solution treatment and subsequent aging heat treatments so that the most suitable material may be made available for a specific purpose, is of vital importance to industry.

Aging may be retarded to zero rate at sufficiently low temperatures. A practical application is the storage of light alloy rivets in cold boxes until ready for use. Such storage can continue for an indefinite time without any hardening.

On the other hand, accelerated precipitation hardening is commercial in America. This process has been termed "double aging" and consists of heating the alloy to the solution temperature, quenching, and reheating to a suitable precipitation temperature, strain hardening, and again reheating to a suitable temperature. The strain hardening may be induced either by the rate of cooling from the first reheat or by cold working.

Dilation of a part ("growth") may be appreciable in ferrous and non-ferrous alloys if they are machined immediately after drastic quenching; this volume change is reduced if the chilling is less severe and is not detectable if machining is carried out after the normal age hardening process is complete. These facts are of immediate importance to engineers in industry when materials of definite dimensions are required.

In other types of alloys growth is associated with phase changes in one or more of the constituents. Such gradual allotropic changes are a variety of aging, and they can be greatly retarded by a small amount of another metal. A specific example taken from the die casting industry is the stabilization of zinc-aluminum alloys with a little added magnesium.

The use of ferrous and non-ferrous alloys at high temperatures is a most important problem. The ideal alloy should not soften to any appreciable extent at the maximum temperature at which it is likely to be exposed. It has, however, been found that alloys which age harden respond to different temperatures of heat treatment according to their compositions, but it is not always convenient or desirable to use an alloy which appears entirely suitable for the purpose in question; hence the need for the development of new alloys for specific purposes. *(Continued on page 420)*

NOTES ABOUT AUTHORS IN THIS ISSUE

THE STUDY of earth-boring tools and methods of their improvement and treatment has occupied most of the professional career of **Charles H. Shapiro.** Soon after graduation from Colorado University, as a chemist-metallurgist, he entered the employ of the Denver Rock Drill Co. His experience in this work led him into problems of similar nature in the oil well drilling field. The years 1923 to 1926 he spent as an associate metallurgist with the Bureau of Mines in a special study of fishtail bit steels and their proper treatment in oil field shops. For the past 13 years Mr. Shapiro has been chief metallurgist of the Reed Roller Bit Co. of Houston, Texas. He has been actively interested in and has followed the development of most types of hard surfacing metals and their application to oil drilling tools since the inception of this material. Mr. Shapiro participates in the activities of a number of technical societies and is at present chairman of the Texas Chapter.

Two young hydraulic engineers undoubtedly enjoyed dividing the third prize of some $1500 in the recent Lincoln Arc Welding Competition. **Jean Marcus Mousson II** has been hydraulic engineer for Safe Harbor Water Power Corp., Baltimore, for the past ten of his 34 years. He had eight months' previous experience with Electric Bond and Share Co. and is a graduate of the Swiss Federal Institute of Technology. **LeRoy Milton Davis** has been with Pennsylvania Water & Power Co. for the past 8½ years in the capacity of hydraulic test engineer. Born 38 years ago, graduated from Cornell University, he spent five years as engineer of hydraulics with the Niagara Falls Power Co. and two years as design engineer, Aluminum Co. of America. The pre-welding of turbine blades described in their article is said to have resulted in a direct saving to the Safe Harbor Water Power Corp. of $17,500.

Peter Payson considers himself fortunate in having had the guidance and friendship of John A. Mathews of Crucible Steel Co. from the beginning of his career until Dr. Mathews died in 1935. Mr. Payson has been with Crucible Steel Co. of America since his graduation from Columbia Engineering School in 1922 with a metallurgical engineering degree. He worked in the metallurgical laboratory of the Halcomb Steel Co. in Syracuse (a Crucible subsidiary) until 1929 when the research laboratory at Harrison was organized and he was placed in charge. Mr. Payson has four U. S. patents on high alloy steels.

Junior author of the article on austempering is **Walter L. Hodapp,** a 1934 graduate of Lehigh University with a degree of B.S. in metallurgy. He spent one year with U. S. Metals Refining Co., and since 1936 has been metallurgist in the Crucible Steel Co. research laboratory in Harrison, N. J.

LeRoy M. Davis

Peter Payson

Walter L. Hodapp

Jean M. Mousson II

Charles H. Shapiro

AGE HARDENING

(Starts on page 354)

The question of creep at high temperatures plays a most important part in connection with this problem. The relation of aging to creep is one of immense theoretical and practical importance. Cold work — that is, plastic deformation at room temperature — has a marked influence on the rate of age hardening; plastic deformation, such as occurs as a result of creep at elevated temperatures, must therefore have a far reaching effect, since the process of aging is accelerated both by rise in temperature as well as by the stress imposed. Creep is a subject which is, however, receiving much attention both from the experimental as well as the practical point of view.

The corrosion resistance of alloys which can be age hardened is another problem of industrial importance. For a given composition of the alloy the desired mechanical properties are intimately connected with high corrosion resistance. The data regarding the aging of alloys at different temperatures — if correctly used — will fortunately enable the manufacturer to produce alloys having the highest possible corrosion resistance associated with the best mechanical properties.

Another example of the practical importance of age hardening is seen in the similarity between the mechanism of the nitride hardening of steels and that of age hardening. Two hypotheses concerning the nature of nitride hardening have been suggested: (1) That the presence of aluminum causes the precipitation of aluminum nitride during nitriding and that this finely dispersed phase is the cause of hardening; (2) the substitution of aluminum atoms for certain of the iron atoms in the several phases composed of iron and nitrogen (in the same manner that the substitutional iron-aluminum solid solution is formed). In this second hypothesis the marked increase in hardness is attributed to the severe lattice distortion accompanying this replacement.

These few examples illustrate the great importance of the phenomenon of aging to industry. There are many other examples of its application, and it is probable that more will arise in the future. In certain cases aging in an alloy may be a distinct hindrance, particularly when it may result in adverse changes occurring during creep at high temperatures. On the other hand, the development of an alloy for high temperature may lie in the direction of producing one whose satisfactory properties cannot be attributed to age hardening, and it is probable that such an alloy will be very complex, possessing little, if any, variation in solid solubility at different temperatures, and hence structurally very stable.